ACTS—AN ABET COMPLIANCE TRACKING SYSTEM FOR ASSESSING STUDENT OUTCOMES

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Abstract

There is nearly universal agreement among engineering educators that the ABET2000 rules, although very well intentioned, have unintentionally increased the workload required to document that all ABET outcomes (a through k) are met, and that a process of continuous improvement is in place. Although there is no magic wand to eliminate all of the documentation and record keeping, organization and technology can be used to considerably reduce the time needed for the ongoing self-assessment process. Towards this end, the Department of Electrical and Computer Engineering at Binghamton University has created a WEB hosted database system, referred to as the ABET Compliance Tracking System or ACTS. In this paper, the preparation of ACTS, its key components, its usage, and continued development are described. ACTS can be readily adapted for use by other engineering programs.

Introduction and Background

Documentation is required to support whether an engineering educational program meets the ABET criteria [1]. The process by which data is collected and analyzed is a significant task. There have been many attempts made to reduce the workload on faculty in this effort. Early discussions on assessment to satisfy the ABET Engineering Criteria 2000 focused on classroom assessment, but not so much on data collection and analysis for program improvement. Shaeiwitz [2] talked about the necessity for feedback in classroom assessment both from current students, as well as, graduates. McGourty et al [3, 4] took this further with a discussion of a five-step assessment strategy and an emphasis on a formal process of assessment. An assessment matrix was introduced by Olds et al [5]. However, this tool was used to help faculty develop an assessment plan and not actually to collect assessment data from students to evaluate program effectiveness. Nevertheless it did provide an example of an increasingly quantitative approach to the assessment process. Felder and Brent [6] introduced a similar matrix-like approach several years later, but included scoring objectives. The scoring objectives weighed the value of each assessment tool (e.g., exams, projects, and presentations) for each student outcome.

Trevisan et al [7] took a more quantitative approach with the use of scoring criteria to assess and report student performance. It was proposed that student performance be assigned a 5, 3, or 1, where a 5 is the highest achieving level of performance. The process included feedback to revise the scoring criteria as needed. DeLyser and Hamstad [8] took a very thorough approach to assessing and recording student outcomes with faculty-kept notebooks that correlated ABET Criteria 2 and 3, program educational objectives, the assessment schedule and performance criterion, and measurements. This was an entirely paper-based system. Blandford and Hwang [9] introduced a web-based site for class assessment. The site had course objectives and outcomes and a feedback mechanism that consisted of a list of recommendations for course improvement. This promoted some consistency in the assessment process among the faculty.

In 2006 a relational database for continuous program improvement was proposed by Booth [10] in a computer and information science education program to better map Program Outcomes (now called Student Outcomes) and course objectives for the ABET-CAC criteria. This client-server system consisted of a web browser, a web server, and a database management system. This system did not, however, address the mechanism by which program improvement is documented. Most recently (2010) Essa et al [11] has developed a web-based software tool to facilitate course assessment. The tool is called ACAT (ABET Course Assessment Tool). HTML is used to display pages to the user. The HTML is generated using PHP server side scripting and data stored in a MySQL database. While this tool's implementation is similar to the one described in this paper it is not made clear what the feedback mechanism is for continuous improvement in program or student outcomes.

Several other engineering educators have also addressed the issues of efficiently assessing ABET engineering criteria, especially outcomes a-k, listed under criterion 3. The comprehensive paper by Felder and Brent [6] address many of the issues involved in designing and teaching courses to satisfy ABET assessment expectations. Their paper also includes a comprehensive bibliography of related papers.

Development of ACTS

The development of ACTS began with defining the Student Outcomes (originally called Program Outcomes) themselves, each of which is then assigned a "Meaning" that is used to define the essential "Elements" that make up the outcome. Each element is then decomposed into "Performance Criteria" that provide further refinement of the outcome. The outcomes, in total, account for each of the a-k required ABET outcomes plus any additional outcomes selected for the program. Each Element of each Outcome is explicitly linked to a set of "Performance Criteria" chosen to capture specific skills or attributes that support the Element. A Performance Criterion corresponds to a specific Course Objective in the Electrical or Computer Engineering curriculum. The diagram in Figure 1 illustrates the linkage between these levels in the process. The department Undergraduate Studies Committee (USC) has responsibility for establishing and maintaining the Outcomes, Elements and Performance Criteria.

To better illustrate the hierarchy of relationship depicted in general terms in Figure 1, a specific example of Electrical Engineering (EE) Student Outcome #5 is given in Table 1, mapped to its Meaning, Elements, and Performance Criteria. The other 11 student outcomes are similarly mapped. In total, 54 performance criteria are defined for the EE program, and 53 performance criteria are defined for the computer engineering (CoE) program. As shown in Table 1, the Meaning of Outcome #5 is defined and broken down into three key Elements, which are numbered 5.1, 5.2, and 5.3. Each of these Elements is further mapped to a set of Performance Criteria, which have been selected by the Undergraduate Studies Committee as being representative of these Elements. Each Performance Criterion is a demonstrable ability that is quantitatively and qualitatively assessed by the instructor teaching the corresponding course. The primary tool the Undergraduate Studies Committee uses to monitor all of this assessment data on a periodic basis (every semester) is the ACTS, as described in this paper.

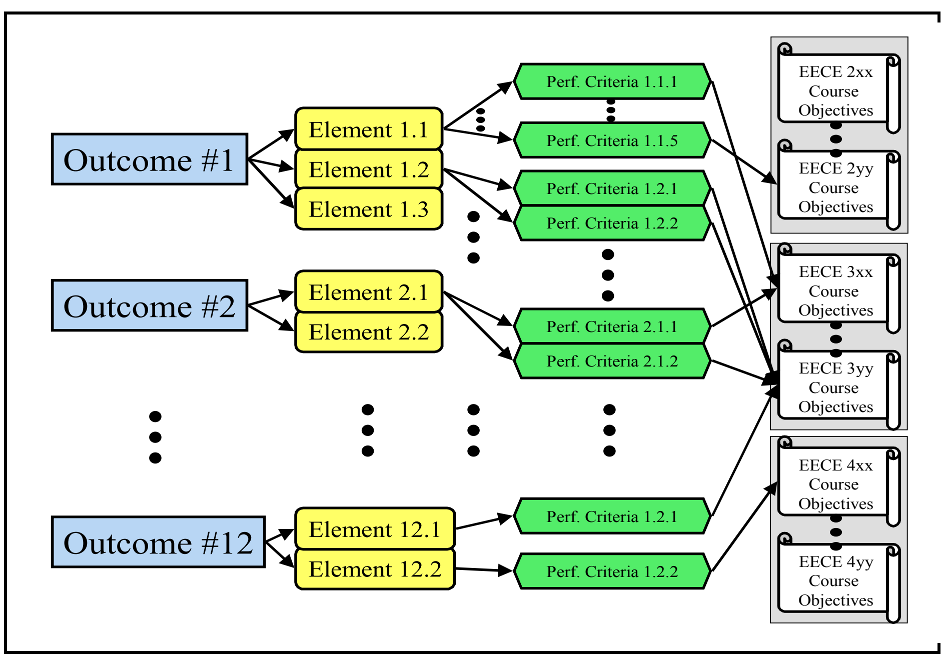

Figure 1. Hierarchy of relationships from student outcomes to course objectives.

Table 1. Student Outcome #5, its Meaning and Elements, and the Performance Criteria that directly link this outcome to specific Course Objectives.

Outcome EE-5:

The ability to identify, formulate, and solve electrical engineering problems.

Meaning

Engineering requires the graduate to work in a design space that has a number of constraints. An engineer uses his or her knowledge of math, science, and engineering principles to design and build systems by means of synthesis processes. Engineering solutions often use approximations, consider only a range of operability, and are often limited by time and cost constraints.

This outcome consists of the following:

EE-5.1: the ability to identify electrical engineering problems (knowledge level)

EE-5.2: the ability to formulate electrical engineering problems (application level)

EE-5.3: the ability to solve electrical engineering problems (all levels of learning since engineering problems are inherently open-ended.

Performance Criteria

EE-5.1.1:	**EECE323 #3:**	Identify and describe sources that produce electromagnetic fields
EE-5.1.2:	**EECE281 #6:**	Write a summary of a technical article and relate the article's ideas to the overview of the electrical and computer engineering
EE-5.2.1:	**EECE301 #13:**	Use Z-transform methods for analysis of discrete-time linear systems
EE-5.2.2:	**EECE387 #3:**	Formulate engineering problems from specifications.
EE-5.3.1:	**EECE323 #5:**	Solve electrostatic and magnetostatic problems
EE-5.3.2:	**EECE377 #6:**	Specify a specific passband analog communication scheme and its parameters to achieve requirements on bandwidth, power, and error performance.

To ensure a firm linkage between the Course Objectives and Performance Criteria (and ultimately, the Student Outcomes) a set of course objectives has been defined by the faculty for every course offered in the Electrical and Computer Engineering Department. These course objectives are specific and define the minimum set of abilities that a student who successfully completes the course must achieve. The course objectives are determined by the faculty as a whole and require faculty approval to change. Although an instructor cannot unilaterally modify existing course objectives, he/she can supplement them as long as the minimum set of objectives is fulfilled. This process ensures an effective methodology for assessment of the Student Outcomes; each Outcome is assessed directly by assessing the Performance Criteria assigned to it; more detail on the assessment process is given below.

Features of ACTS—the ABET Compliance Tracking Tool

Although several tools are used in the assessment process, the primary tool used and the topic of this paper is the Web-based assessment tool ACTS. This tool has the following assessment components:

A. Numerical Assessment of Performance Criteria by Instructor
    1. Evaluation of performance on specific learning tasks (e.g., exam/quiz problems, project reports, presentations) that focus on the explicit Performance Criteria assigned to the course; and

2. Although not yet incorporated directly in ACTS, all performance criteria are supported by electronic copies of collected work and labeled according to ACTS notations.

B. Instructor's qualitative evaluation of student preparation for course.
C. Instructor's qualitative evaluation of the class's achievement of Performance Criteria and Course Objectives and suggestions for improvements
D. Comments from the Undergraduate Studies Committee responding to instructor's evaluation and providing feedback from the assessment process directly to the instructor.

The two main aspects of the assessment process are to (i) measure the level of achievement of the Student Outcomes and to (ii) determine ways to improve the curriculum relative to the Outcomes. The four components of ACTS, listed above can be used as either primary or secondary tools for both of these aspects. In the ECE department at Binghamton, ACTS is the primary assessment tool for both measuring achievement and determining improvements in both the CoE and EE programs. Since 2007, it has been modified and adopted for assessment purposes in the computer science department at Binghamton. A major advantage of ACTS is the ease with which data can be collected and analyzed. It is easy to manage the collection process and to monitor whether course assessments have been completed.

All instructors teaching in a given semester have access to the ACTS system throughout that semester. For each course taught the instructor evaluates the class for particular assigned performance criteria and indicates which course evaluation tools were used (e.g., a specific exam problem, lab exercise, etc.). Based on the performance on that evaluation tool, the instructor determines the percentage of students who are in the following categories:

Level #1: *Student partially meets the expected level of achievement on the stated objective.*
***Level #2**: Student demonstrates satisfactory achievement on the stated objective.*
***Level #3**: Student demonstrates very good to excellent performance on the stated objective.*

Approximately, these levels correspond to grades on a specific evaluation tool, with level 1 being grades of "D" or "F," level 2 a "C" grade, level 3 a "B" or "A" grade. An assessment score for each Performance Criteria is computed by ACTS. These scores (as well as the percentages in each level) form the main set of numerical metrics that are used to demonstrate *achievement* of each Student Outcome. Examples of student work are also collected to support this evaluation and are stored in a course folder electronically as pdf files. Figure 2 depicts a screenshot from ACTS showing quantitative scores entered for EECE382 (Junior Seminar) for Spring 2006. For each of the 3 performance criteria assigned to that course, the evaluation tools used by the instructor to assess student performance are listed. For each performance criterion, the instructor has entered the number of students for each of the three performance levels; an average score has been computed by the system.

In addition to quantitative assessment, ACTS provides three qualitative assessment tools. The first two provide a mechanism for the instructor to assess the performance of the students coming into and leaving the course. The third provides a mechanism for the Undergraduate Studies Committee to feed information back to the instructor. These qualitative tools evaluate:

1. the quality of preparedness of the students coming into the course, including changes observed from previous semesters;
2. the level of achievement of the course objectives, including problems encountered and suggested changes to course objectives; and
3. a response from the Undergraduate Studies Committee responding to instructor comments, providing a direct feedback path from the assessment process to the instructor.

Figure 3 shows a screenshot from ACTS showing the qualitative assessment entered by an instructor. The top text box shows the instructor's comments on student preparedness. The middle box shows the instructors comments on how well course objectives were met and recommendations to the Undergraduate Studies Committee. The bottom text box shows the response made by the Undergraduate Studies Committee to the instructor's comments. The instructor can incorporate this feedback into the course the next time it is offered.

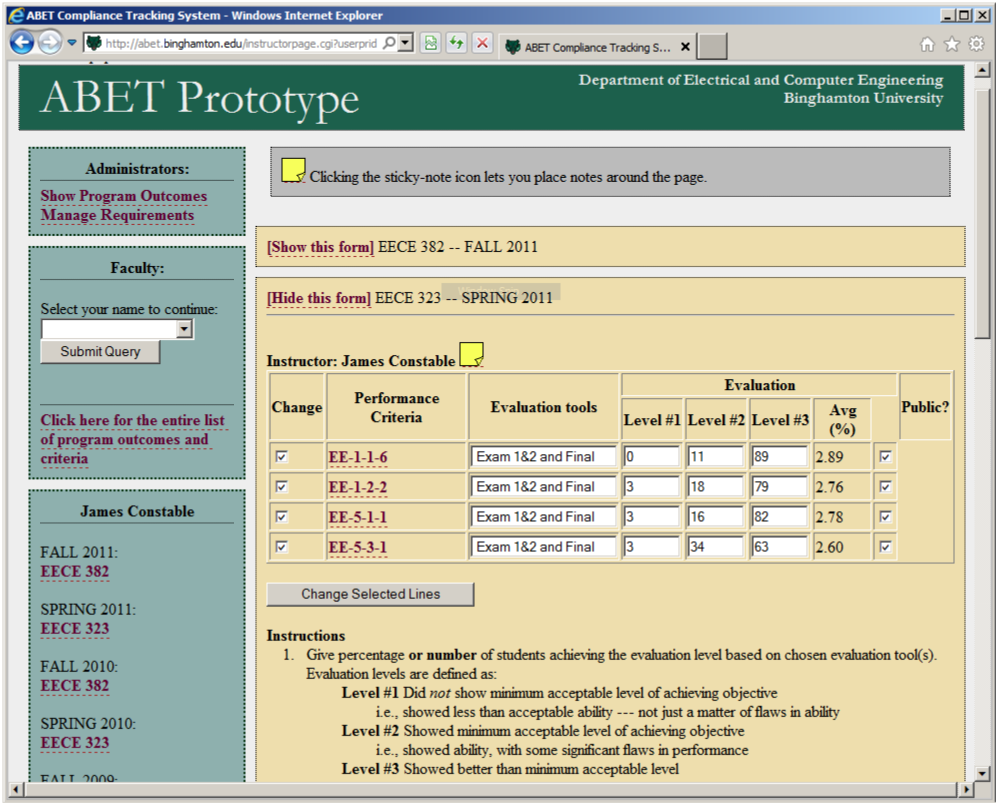

Figure 2. Screenshot taken from ACTS system showing quantitative performance data entered by an instructor.

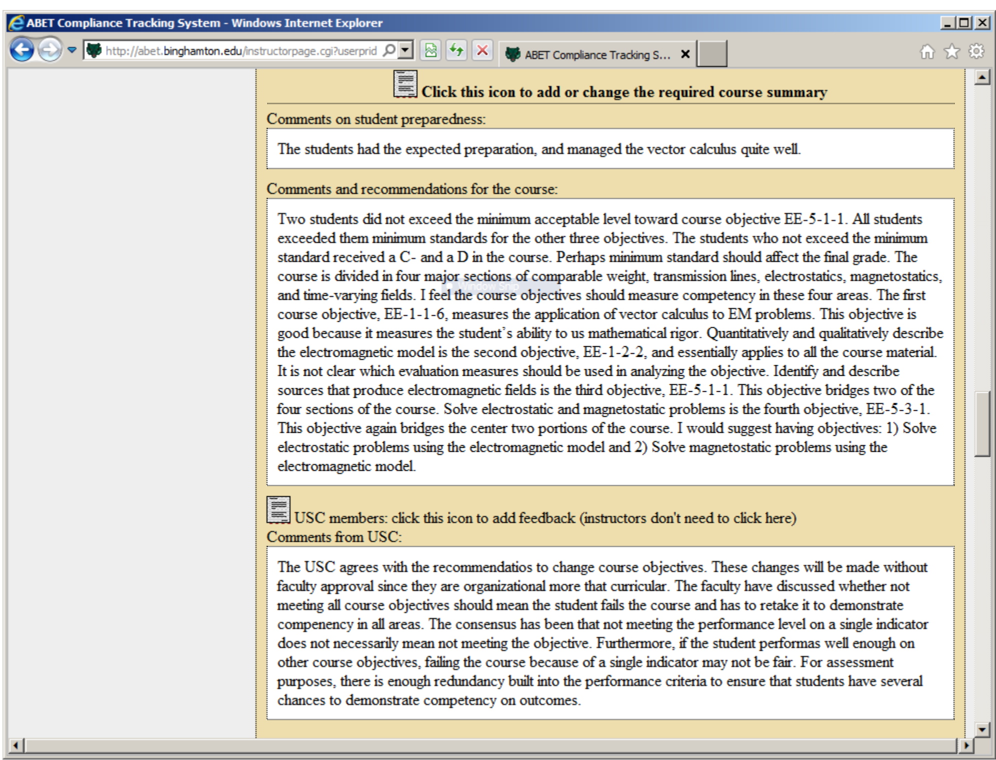

Figure 3. Screenshot taken from ACTS system showing qualitative data entered by an instructor.

ACTS Implementation

The ACTS system follows a straightforward architecture of a MySQL database backend, fronted by server-side PHP scripts. The database is normalized to third normal form (3NF) and comprises tables to describe instructors, courses, and course sections; ABET outcomes, attributes and course performance criteria; and data on performance criteria for individual course sections.

The largest challenge of ACTS was the interface design. The agreed upon design constraint was that the new system should not require any additional training or incur any additional complexity over an earlier paper system; the new system should only make the process faster and more manageable. This meant that the system should closely mimic the format of the previous paper forms. However, only that much of the form data would be automatically filled out.

The number of mouse clicks needed for an instructor to get to this form, to fill it in and submit it, were minimized. Upon entering the ACTS system, the instructor chooses his/her name from a drop-down list (two clicks for selection, one click for the "submit" button) and is presented with a list of the instructor's course sections, present and past. These are listed in reverse chronological order and collapsed to prevent the need to scroll the page. The instructor then chooses the appropriate course section (one click) and sees a copy of the previously used paper course assessment form. The performance criteria to be assessed are already laid out (the instructor does not need to cross-reference a master list of criteria to be assessed for the course), and only the learning task and number of students in each performance category need to be added (one click to enter the text area.) The aggregate statistics that were previously hand computed from the paper form are now automatically computed by the server instead.

A second challenge of ACTS is the fluid nature of performance criteria and outcomes. Occasionally the set of outcomes and criteria are restructured; in Fall 2009 the outcomes and attributes were reorganized to be more closely aligned with ABET a-k outcomes, and the Performance Criteria were revised to be more efficiently assessed by our curriculum. However, new versions must be compatible with entries from previous years. It was thus necessary to add dates of enactment and revocation throughout the database, and ensure that all code connects to the proper version for the course being displayed.

Beyond these two issues, the computerization of our system made the assessment process extremely easy to manage. Subsequent tasks were a matter accomplished in minutes by writing a short PHP program. These included: producing a list of instructors who have not yet entered their ABET data; producing a summary of numerical assessment data to plot year-over-year; and amending the forms to include free text comment fields for the Undergraduate Studies Committee to enter remarks on each course section.

Process for Assessing the Outcomes and Improving the Program

As mentioned above, the outcomes assessment process enables each professor to directly contribute to the assessment of student outcomes rather than merely course objectives. To accomplish this, as mentioned previously, the Undergraduate Studies Committee identified the key elements of each student outcome and defined specific performance criteria, chosen from the set of course objectives, which can be used to demonstrate achievement of these key elements. Each instructor, by assessing the Performance Criteria assigned to his/her course, is therefore directly contributing to the assessment of the Student Outcomes.

In addition to specifying the performance criteria, specific guidelines have been established to arrive at a numerical assessment score for the performance criteria. These guidelines help ensure assessment consistency.

The assessment process is described here in the chronological order in which its steps occur. The process is also depicted graphically in Figure 4.

A. Start of Semester: Instructors are directed to the ABET Compliance Tracking System (ACTS) site to find:

- The list of performance criteria that are assigned to their course(s); and
- The assessment form and directions on how to complete the assessment.

This is typically done at the pre-semester faculty retreat and continues into the first department meeting of the semester if necessary. This ensures

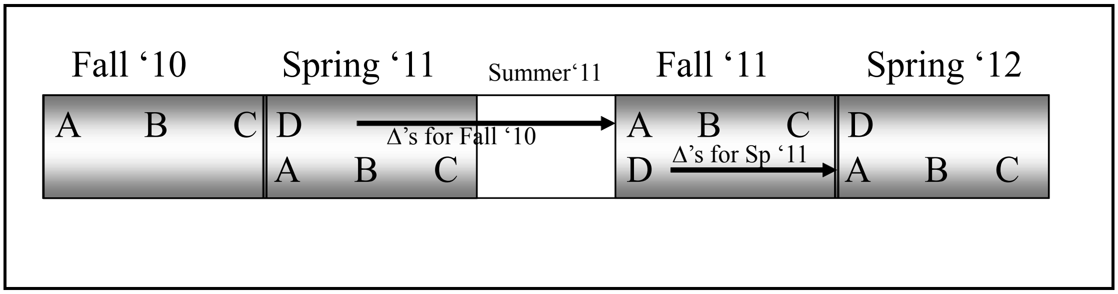

Figure 4. Timeline for the assessment and improvement process showing the activities over two academic years. Note that changes for Fall (Spring) courses are identified during the Spring (Fall) semesters allowing them to be implemented the very next time the course is offered. If feedback were to occur only once a year, then there would be a two-year lag before changes to a course could be implemented.

that every instructor is aware of what and how he/she needs to assess.

B. During Semester: All instructors are reminded that they need to document their course's assigned performance criteria and to enter this information into ACTS. These reminders are made periodically at bi-weekly faculty meetings.

C. End of Semester: Instructors complete assessment:

- Quantitative assessment scores for performance criteria are entered into ACTS;
- Qualitative course assessments are entered into ACTS;
- Each individual course evaluation is summarized in a faculty meeting to identify common and cross-course problems; and
- Collected work supporting assessment of performance criteria is filed in course folders.

D. Beginning of Next Semester: The Undergraduate Studies Committee meets to review the past semester's assessment data. The result of this review includes:

- An assessment of student outcome achievement during the past semester;
- Recommended course/curriculum changes; and
- Recommended changes to performance criteria.

These results are presented and discussed during a faculty meeting. Major issues are generally discussed and major changes agreed to at semi-annual departmental retreats. This is where the faculty as a whole are made aware of course/curriculum changes. Note that this results in assessment feedback occurring every semester, which has a three-fold benefit: more rapid closing of the assessment loop for introducing course improvements; distribution of the assessment activity workload more uniformly across the year; and timely completion of course assessments by instructors.

Analysis of Qualitative and Quantitative Data

Numerical assessment data collected via ACTS are analyzed to demonstrate student achievement with respect to each outcome and to identify areas needing improvement. Figure 5 shows one type of analysis performed on the data. The figure shows a plot of the quantitative assessment data collected for one particular EE class through the end of their third year. For each performance criterion, the plot shows the fraction of students in that class that performed below the minimum acceptable level (red), the fraction that performed at the minimum acceptable (yellow) and the fraction that performed above the minimum level (green). The advantage of this data presentation format is that it is easy to identify areas in which there may be problems, areas that need to be watched or improved, and areas in which students are doing well. For example, in earlier years, inspection of the quantitative data showed that the ability to apply probability (outcome 2) was a problem, and additional review of probability was included in several courses at the junior and senior level. Every semester, plots are made for the sophomore, junior, and senior classes.

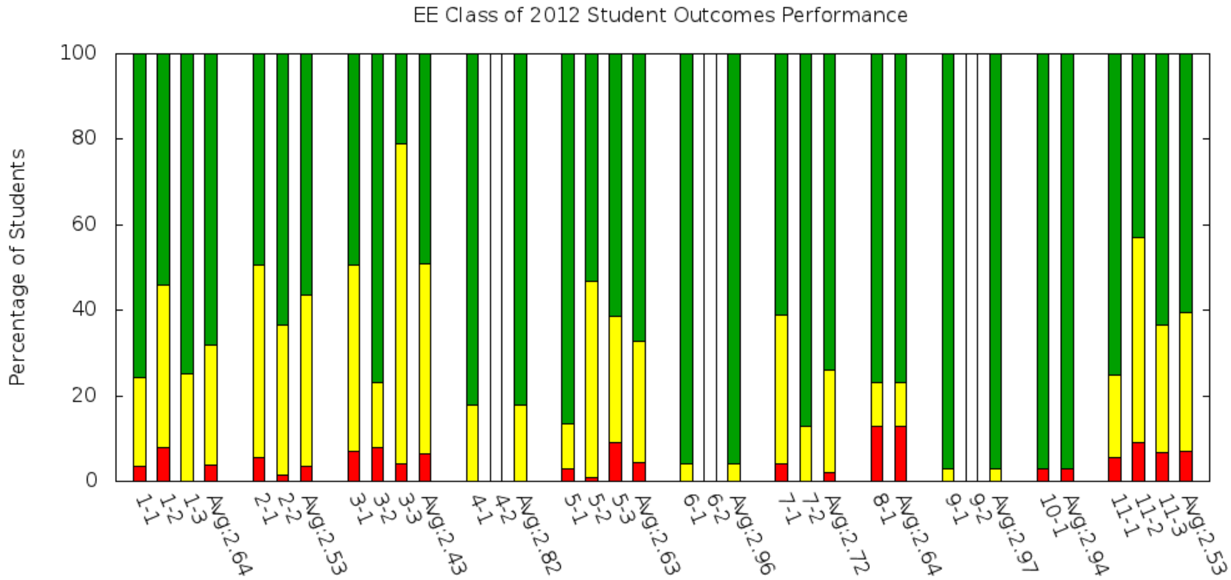

Figure 5. Plot of class of 2012 performance on all student outcomes. Green indicates level 3 (best), yellow level 2 (intermediate), and red level 1 (below expected) performance.

Trends can be plotted by comparing data across different class years. For example, it is possible to compare the graph in Figure 5 to the corresponding graph for the same class one year earlier in the assessment cycle and thus to spot changes and longer term trends. These trends can be analyzed and explained with the help of qualitative assessment and correlated with changes made in the curriculum.

After the course assessment data have been entered into ACTS, the Undergraduate Studies Committee (USC) downloads the qualitative and numerical data for each course. The data are analyzed and discussed in the context of current and prior assessment cycles. Prior changes are evaluated to determine their effectiveness. When appropriate, the USC makes a written response that includes either a proposal for change in course objectives (or other course of action) or a recommendation that the issue be watched and revisited in the future when further assessment data become available. Each of these is then openly discussed at a faculty meeting and, in the case of curricular or other significant changes, voted on by the faculty.

Improvements to the Assessment Process Itself

As a result of a previous ABET visit it became clear that the method then in place of using a matrix to connect course objectives to the student outcomes was inadequate. Improvements to be implemented were primarily aimed at (i) making the collection of course assessment data more efficient, uniform, and effective, (ii) enabling instructors to *directly* contribute toward assessment of Student Outcomes, and (iii) ensuring sufficient assessment of all outcomes. All of these improvements were implemented by constructing and using ACTS. As a result of our most recent ABET visit, the department decided to revise course outcomes to directly correspond to ABET a-k. A small amount of work was required to redefine some of the performance criteria and change the linkages to specific ABET outcomes. The changes in ACTS itself were made in fewer than eight hours of work. New features in ACTS that will make it easier to analyze the collected numerical data are currently being developed.

Conclusions

A WEB based assessment tool, ACTS (ABET Compliance Tracking System) has been described. This tool is the primary assessment tool for monitoring the degree to which various elements of each student outcome are met. The tool has advantages of ease of use, flexibility for making changes, convenient reminders for all faculty as to what assessment is expected for each required course, very low overhead for entering and maintaining data, and ease of interpreting and using results for continuous program improvements. As a result, in the Binghamton EE and CoE programs, every ABET outcome is assessed every year.

Adapting ACTS for other programs is a straightforward task, although at its current level of development it would require a programmer on site to manage the transition. ACTS can be used in any environment in which there are courses taught by instructors, which should be tied to performance criteria set by student outcomes. To adapt ACTS to a local environment, a department would first have to specify a list of student outcomes to assess, for example the ABET a-k outcomes. These can then be detailed by attributes, which can be seen as specific sub-goals of each outcome, and performance criteria that are in turn sub-goals of the attributes. Then, specific course objectives can be tied to performance criteria, so that each course will show appropriate entries for the criteria being assessed.

All of this can be added to the ACTS system directly through a web interface, although performing any detailed manipulation on the outcomes generally requires direct database access. In any case, it is strongly encouraged to determine all necessary outcomes, criteria, and performance-criteria relations before entering any data. We have found that an ideal process for producing this data is simultaneously top-down and bottom-up: one person fixes the student outcomes, and then each instructor attaches a list of explicit course goals to the course's syllabus. These goals are best made concrete so as to be explicitly tested by exam and homework questions. For example, rather than writing "the student should understand conditional probability," it is better to write, "the student should be able to solve conditioning problems," or "apply Bayes' rule." Finally, the syllabi are merged with the student outcomes and specific course goals are selected as performance criteria.

ACTS can be made available to any programs interested in adopting it. If interested, please contact co-author Scott Craver. Some local database programming expertise would be required, to make the modifications mentioned above, as programming support cannot be provided by any of the authors of this paper.

Acknowledgement

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