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## **AC 2011-302: ABET COMPLIANCE TRACKING SYSTEM (ACTS)**

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# ACTS—an ABET Compliance Tracking System for Assessing Engineering Outcomes

## 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

Several engineering educators have addressed the issues of efficiently assessing ABET engineering criteria, especially outcomes a-k, listed under criterion 3. Felder and Brent<sup>[1]</sup> have written a comprehensive paper on 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 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 Computer Engineering (CoE) Program Outcome #5 is given in Table 1, mapped to its Meaning, Elements, and Performance Criteria. The other 11 program outcomes were similarly mapped. In total, 53 performance criteria were defined for the CoE program, and 54 performance criteria were defined for the electrical engineering (EE) 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.

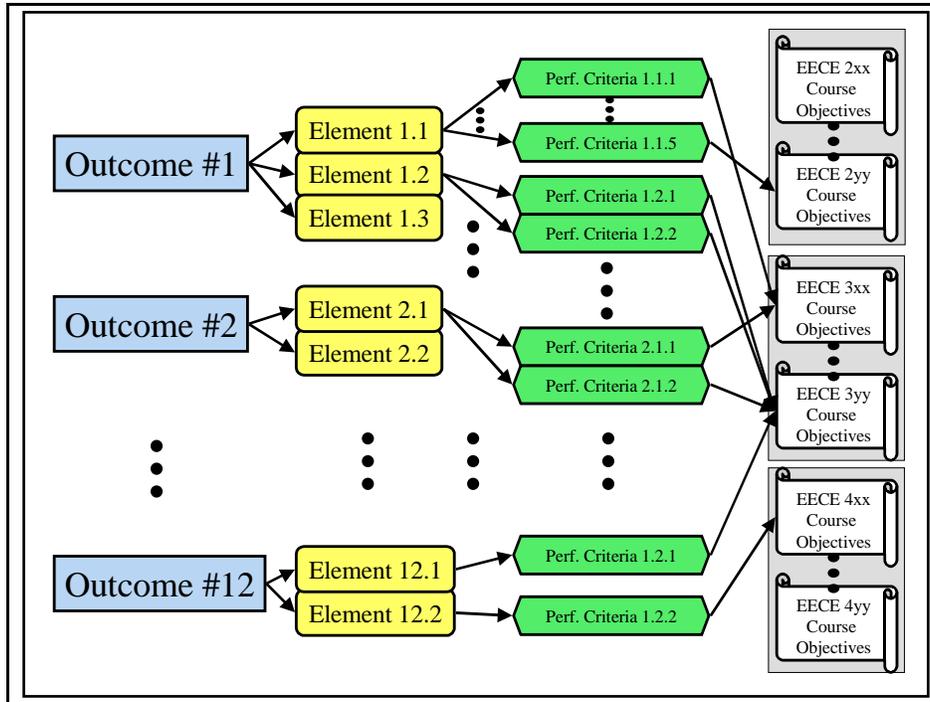


Figure 1. Hierarchy of relationships from program outcomes to course objectives.

To ensure a firm linkage between the Course Objectives and Performance Criteria (and ultimately, the Program 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 Program 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
  2. Supported by Collected Work
- 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.

Outcome	5. The ability to analyze electronic devices & circuits, software components, and systems containing hardware and software.
Meaning and Elements	<p>In engineering, analysis usually consists of breaking down a complex problem into parts. Each part can then be further broken down or be solved by application of engineering principles. Analysis, a key component in the design process, requires an understanding of both the content and the structural form of the material.</p> <p>This outcome is at the analysis level and encompasses three attributes:</p> <p>5.1 the ability to analyze electronic devices &amp; circuits,  5.2 the ability to analyze software or algorithms, and  5.3 the ability to analyze systems containing hardware and software</p>
Performance Criteria	<p>Student will have successfully achieved this program outcome by demonstrating the following:</p> <p>CoE-5.1.1: <b>EECE315 #3:</b> Perform analysis of circuits containing diodes and transistors.</p> <p>CoE-5.1.2: <b>EECE351 #5:</b> Sketch a timing diagram for a synchronous sequential circuit.</p> <p>CoE-5.2.1: <b>EECE252 #4:</b> Analyze a sequence of assembly language instructions to determine its execution time as well as how it affects the contents of registers and memory.</p> <p>CoE-5.2.2: <b>EECE352 #1:</b> Analyze and evaluate the performance of computer systems using various metrics such as Millions of Instructions per Second, Instructions per Cycle.</p> <p>CoE-5.3.1: <b>EECE352 #3:</b> Design and evaluate the performance of the memory subsystem in a computer system.</p> <p>CoE-5.3.2: <b>EECE387 #8:</b> Analyze a system containing hardware and software to determine its operational characteristics and limitations.</p>

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

The two main aspects of the assessment process are to (i) Measure the level of achievement of the Program 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 that are in the following categories:

**Level #1:** *Student does not show minimum acceptable level of performance*

**Level #2:** *Student shows minimum acceptable level of performance*

**Level #3:** *Student demonstrates good performance*

**Level #4:** *Student shows mastery of performance achieving stated objective.*

Effectively 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” grade, and level 4 an “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 Program Outcome. Examples of student work are also collected to support this evaluation and are stored in a course folder. Figure 2 depicts a screenshot from ACTS showing quantitative scores entered for EECE352 (Computer Architecture) 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 four 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.

The screenshot shows the ABET Prototype web interface for the Department of Electrical and Computer Engineering at Binghamton University. The page is titled "ABET Prototype" and "Department of Electrical and Computer Engineering Binghamton University".

On the left sidebar, there are sections for "Administrators:" (Show Program Outcomes, Manage Requirements) and "Faculty:" (Select your name to continue: dropdown menu, Submit button). Below this is a link: "Click here for the entire list of program outcomes and criteria". At the bottom of the sidebar, the name "Mark Fowler" is listed with a list of course sections: FALL 2010: EECE 301; FALL 2009: EECE 301; FALL 2008: EECE 301; SPRING 2008: EECE 301.

The main content area has a sticky-note icon and text: "Clicking the sticky-note icon lets you place notes around the page." Below this are two tabs: "[Show this form] EECE 301 -- FALL 2010" and "[Hide this form] EECE 301 -- FALL 2009". The "Show this form" tab is active.

The instructor is identified as "Mark Fowler". Below this is a table of performance data:

Change	Performance Criteria	Evaluation tools	Evaluation				Avg (%)	Public?
			Level #1	Level #2	Level #3	Level #4		
<input checked="" type="checkbox"/>	CoE-1-1-1	Examlet #3	2	10	10	9	2.84	<input type="checkbox"/>
<input checked="" type="checkbox"/>	CoE-11-1-1	Examlet #4, Prob #1	0	12	4	8	2.83	<input type="checkbox"/>
<input checked="" type="checkbox"/>	CoE-1-1-2	Examlet #6, Prob #2	2	8	9	13	3.03	<input type="checkbox"/>
<input checked="" type="checkbox"/>	EE-1-1-1	Examlet #3	0	14	10	8	2.81	<input type="checkbox"/>
<input checked="" type="checkbox"/>	EE-11-1-1	Examlet #4, Prob #1	0	9	4	14	3.19	<input type="checkbox"/>
<input checked="" type="checkbox"/>	EE-1-1-2	Examlet #6, Prob #2	0	2	10	22	3.59	<input type="checkbox"/>
<input checked="" type="checkbox"/>	EE-1-1-5	Examlet #1, Prob #1	1	1	10	24	3.58	<input type="checkbox"/>
<input checked="" type="checkbox"/>	EE-5-2-1	Final Exam, Prob #1	1	13	8	13	2.94	<input type="checkbox"/>

At the bottom of the table is a button labeled "Change Selected Lines".

Figure 2. Screenshot taken from ACTS system showing quantitative performance 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.

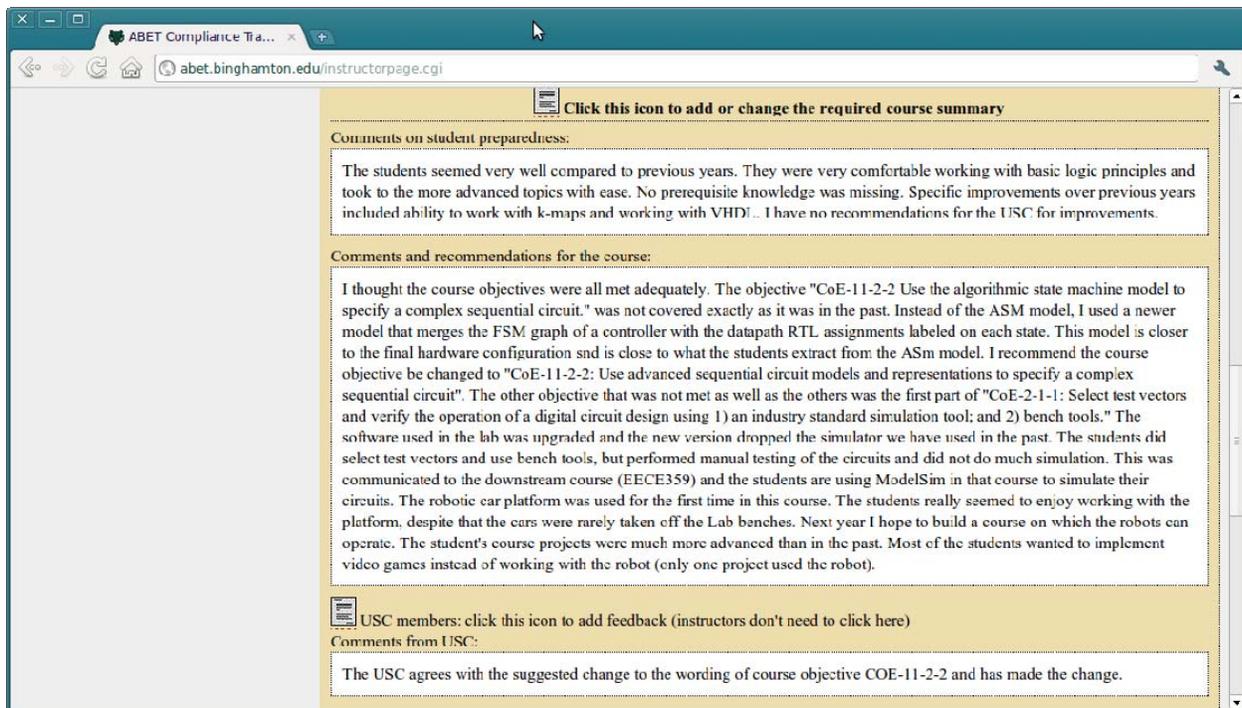


Figure 3. Screenshot taken from ACTS system showing qualitative data entered by an instructor.

The largest challenge of ACTS was the interface design. We worked under the design constraint 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, only that much of the form data would be automatically filled out.

We sought to minimize the number of mouse clicks needed for an instructor to get to this form, to fill it and submit it. 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 close 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 we reorganized the outcomes and attributes to be more closely aligned with ABET a-k outcomes, and revised the performance criteria 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 has 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 program outcomes rather than merely course objectives. To accomplish this, the Undergraduate Studies Committee has identified the key elements of each program 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 program 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.

**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)
- ▶ 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 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
- ▶ 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 program outcome achievement during the past semester
- ▶ Recommended course/curriculum changes
- ▶ 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 achievement of outcomes and to identify areas needing improvement. Figure 4 shows one type of analysis performed on the data. The figure shows a plot of the quantitative assessment data collected for one particular CoE 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, 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.

Trends can be plotted by comparing data across different class years. For example, it is possible to compare the graph in Figure 4 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 program 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 Program 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 program 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.

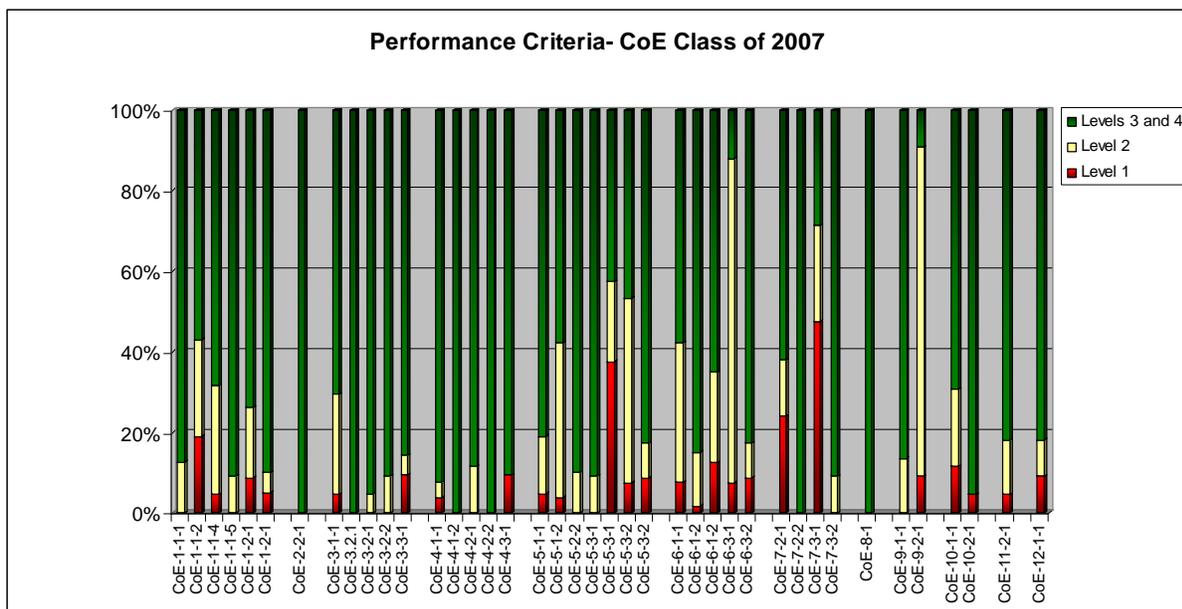


Figure 4. Summarized assessment data from Fall 2005 for the CoE Class of 2007.

Adapting ACTS for other programs is a straightforward task, although at this level of technological 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 program outcomes. To adapt ACTS to a local environment, a department would first have to specify a list of program 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 tends to require 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 program 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: 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 program outcomes and specific course goals are selected as program outcomes.

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.

## **Bibliography**

1. Felder, R. M. and Brent R., 2003, Designing and Teaching Courses to Satisfy the ABET Engineering Criteria, *Journal of Engineering Education*, 92(1), 7-25