ABET EC 2000: Quantifying the Assessment of Outcomes

Martin R. Parker[1] and William A. Stapleton[2]

Abstract

ABET-accredited engineering Programs, whose re-accreditation becomes due within the 3-year period, 1998-99 through 2000-01, may elect to be assessed on the basis of the new Engineering Criteria 2000 (EC 2000). A central feature of these new criteria is a requirement of Programs under evaluation by the Board to demonstrate clearly that, at the very least, eleven separate learning objectives (outcomes) are being achieved. Such evidence can only be provided by a comprehensive assessment of outcomes. Additionally, within the framework of EC 2000, the engineering curriculum is perceived as a dynamic system, subject to continual change in response to this assessment. Methods of assessment of outcomes have been widely discussed by academics in recent months. Several of the more high-profile approaches (student grades, retention rates, FE exam results, graduate school admissions, employment statistics, etc.) seem to us to be rather limited in their usefulness. Perhaps not surprisingly, we have concluded that the key to better measurement of outcomes as well as to a better process for the achievement of learning objectives lies with the students themselves. This paper discusses how outcomes assessment, involving end-of-semester surveys, seniors' exit interviews, and alumni and employer (supervisor) surveys may be quantified in a meaningful way.

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Introduction

"Assessment" is one of those words that can mean different things to different people. It comes in all shapes and sizes in the teaching of engineering. Until very recently, in university-based engineering programs, it could be interpreted by and large, as a general description for quizzes, tests, homework problems, final examinations, and all similar educational measuring devices that have evolved over several generations. In recent years, the Accreditation Board for Engineering Technology has eliminated such conventional interpretations by introducing a bold revision of the engineering criteria (EC) required of programs seeking re-accreditation around the start of the new millennium. Accordingly, these criteria have become known simply as EC 2000. It is generally acknowledged that the most radical of these is Criterion 3 that deals with eleven specific program outcomes (Fig.1) and the assessment thereof.

Clearly, the key to securing ABET accreditation under these new criteria lies in achieving the outcomes listed in Fig.1. As difficult as this may be, it is obviously even more difficult to demonstrate conclusively that these outcomes have indeed been met. To do so requires some innovation in terms of an assessment toolbox that goes beyond the conventional methods mentioned above. In the following, the construction of an important part of the assessment toolbox is described. A complete description, not given here, would involve the articulation of a set of program objectives that would, demonstrably, correlate well not only with the outcomes of Fig.1, but also with the goals of the department as well as with higher institutional groupings such as college or school.

A. Ability to apply knowledge of mathematics, science and engineering
B. Ability to design and conduct experiments, as well as to analyze and interpret data
C. Ability to design a system, component or process to meet desired needs
D. Ability to function on multi-disciplinary teams
E. Ability to identify, formulate and solve engineering problems
F. Understanding of professional and ethical responsibility
G. Ability to communicate effectively
H. Broad education to understand the impact of engineering solutions in a global and societal context
I. Recognition of the need for, and an ability to engage in life-long learning
J. Knowledge of contemporary issues
K. Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Figure 1: The Eleven ABET Criterion 3 Outcomes

Initial groundwork

A glance at Fig.1 readily confirms that ABET Criterion 3 requires an essential redefinition of a curriculum as a set of learning objectives on a course-by-course, lecture-by-lecture (or lab-by-lab) basis. Accordingly, an ABET EC 2000 course description must reflect this philosophy. More specifically, the heart of any course description should not be a laundry list of subjects to be "covered" but, instead, a finite set of learning objectives, typically ten or less, with some being highly specific and some fairly generic. By way of example, Fig.2 illustrates a portion of an ABET EC 2000 description of a sophomore-level course on digital design with seven clearly stated learning objectives. That such objectives are consistent with (some portion of) the outcomes of Criterion 3 is shown by the matrix of Fig.3. Evidently, a well-conceived bachelor's-level engineering program, comprising approximately 130 semester hours, can be organized in such a way that a master matrix for all of the courses of the program shows strong correlation with all of the eleven outcomes of Fig.1.

EE 264 Digital System Design II

1998-99 Bulletin Data:

EE 264:Digital System Design II. Credit: 3 hours.
Small Computer Organization and Programming. Assembly level programming.
Microprocessor applications to control of physical processes.

Course Coordinator:

Dr. A. A. S …
Associate Professor of Electrical and Computer Engineering

Textbook:

Microprocessor System Design Fundamentals, First edition, Kenneth J. Breeding, Prentice-Hall, 1995

Prerequisites:

EE 263

Course Objectives:

The student will be able to:

1. Understand basic computer organization and structure.
2. Understand use of register transfer notation (RTN).
3. Understand the architecture of the Motorola 6809 microprocessor.
4. Write programs in the Motorola 6809 microprocessor assembly language.
5. Understand the interfacing of serial and parallel I/O devices to the 6809.
6. Understand the I/O support hardware such as counters, timers, A/D and D/A devices.
7. Use the microprocessor as a control device.

Figure 2: Excerpt from an ABET EC 2000 Course Description

Course Objectives/ABET Criteria

Course Number - Course Name											
EE 264: Digital System Design II	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Objective 1	X										
Objective 2	X										
Objective 3	X										
Objective 4	X	X	X		X						X
Objective 5	X	X			X						X
Objective 6	X	X			X						X
Objective 7	X	X	X		X					X	X

Index	
A	Ability to apply knowledge of mathematics, science and engineering
B	Ability to design and conduct experiments, as well as to analyze and interpret data
C	Ability to design a system, component or process to meet desired needs
D	Ability to function on multi-disciplinary teams
E	Ability to identify, formulate and solve engineering problems
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G	Ability to communicate effectively
H	Broad education to understand the impact of engineering solutions in a global and societal context
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Figure 3: Excerpt from Course Objective/ABET Criterion 3 Correlation

Quantifying Formative Assessment

Traditional formative assessment tools include the above-mentioned array of quizzes, tests, and so on. In the context of EC 2000, there is much to be said for augmenting these with other forms of assessment that measure the students' perceptions of what has and what has not been learned. One tool that is easily applied and can be of some considerable use is the "Half-Minute End-of-Class Questionnaire" (Fig. 4) in which easily identifiable topics can be listed by the instructor on a casual but regular basis. The mean and standard deviation derived from the responses are useful numerical indicators for the instructor. This questionnaire can easily be adapted to assess students' perception of their understanding of the same topic(s) immediately following submission of homework or test papers relating to that/those topic(s). The results can be informative and surprising. A second formative assessment tool, shown in Fig.5, is a mid-semester survey (or, alternatively, a pair of early/late surveys). This instrument strives more to put a finger on the students' "pulse", but may also simultaneously give a numerical indication as to whether some of the more difficult to gauge of the Criterion 3 outcomes are being met. For example, question 5 allows a measure of outcome (H) from Fig. 1.

Half-Minute End-of-Class Questionnaire

Course number:_____________ Title:___________________________________

Semester:_________________ Instructor:_______________________________

Note:
This questionnaire is intended to assist the instructor in assessing your comprehension of the lesson. Your cooperation in completing and returning it to the instructor is appreciated.

It is not necessary to identify yourself.

The principal topic(s) of today's class was/were:

(a)____

(b)____

Indicate your level of understanding of this subject matter on a scale of 1 through 10 (10 high). Circle the most appropriate number.

	Low									High
(a)	1	2	3	4	5	6	7	8	9	10
(b)	1	2	3	4	5	6	7	8	9	10

Figure 4: Half-Minute End-of-Class Questionnaire

MID SEMESTER EVALUATION

This questionnaire is intended to assist the instructor in evaluating his/her performance, while the course is being taught. Your cooperation in completing and returning it to the instructor is appreciated.

Course Title________________________________Instructor__________________________________

Semester___________________________________Student (name optional)______________________

Use a scale of 1 to 10 where 1 signifies a very low grade and 10 signifies a very high grade.

• Course content

1. Is the subject matter interesting?
   1 2 3 4 5 6 7 8 9 10 NA
2. Does it relate well to your other courses?
   1 2 3 4 5 6 7 8 9 10 NA
3. Grade the textbook (or lab manual).
   1 2 3 4 5 6 7 8 9 10 NA
4. Grade the practical/theoretical balance of the course/laboratory.
   1 2 3 4 5 6 7 8 9 10 NA
5. Grade the incorporation of "real world" examples into the course material.
   1 2 3 4 5 6 7 8 9 10 NA
6. Grade the design content of the course/lab.
   1 2 3 4 5 6 7 8 9 10 NA
7. Grade the problem-solving content of the course (or of the prelabs).
   1 2 3 4 5 6 7 8 9 10 NA

• Comment on Lectures

7. Is the lecture/lab tutorial presentation good?
   1 2 3 4 5 6 7 8 9 10 NA
8. Are the lectures at:
   (a) too high or (b) too low or (c) just at the right level?
9. Which of these words best describes this course:
   (a) Stimulating (b) Interesting (c) Useful (d) Useless
   (e) Boring (f) Inaudible (g) Other (specify)?

• General Observations

10. How much time per week do you spend studying for this course?
11. Have you any comments that might be useful?

* circle NA where not applicable

Figure 5: Mid Semester Evaluation

END OF SEMESTER EVALUATION

This questionnaire is intended to assist the instructor in evaluation of the extent to which the learning objectives were achieved. Your cooperation in completing and returning it to the EE/CpE office is appreciated.

Name (optional):______________________________________

Course Number__EE264__Course Title____Digital System Design II________________

Instructor________________________Semester ______________1999___

The principal learning objectives set for this course are summarized below. Assess your understanding of each on a scale of 1 to 10 where 1 signifies very low and 10 signifies very high.

1) Understanding basic computer organization and structure
1 2 3 4 5 6 7 8 9 10

2) Understanding use of RTN
1 2 3 4 5 6 7 8 9 10

3) Understanding the 6809 architecture
1 2 3 4 5 6 7 8 9 10

4) Understanding how to write Motorola assembly language programs
1 2 3 4 5 6 7 8 9 10

5) Understanding the interfacing of serial and parallel I/O devices to the 6809
1 2 3 4 5 6 7 8 9 10

6) Understanding the I/O support hardware (counters, timers, A/D & D/A devices)
1 2 3 4 5 6 7 8 9 10

7) Understanding use of the microprocessor as a control device
1 2 3 4 5 6 7 8 9 10

Figure 6: End-of Semester Evaluation

Summative Assessment (Courses)

Traditional summative assessment of students for a course of study is the final letter grade, which is usually predicated strongly on final examination results. An additional assessment tool, consistent with the ABET EC 2000 philosophy and easily applied, is an end-of-semester survey, in which, independent of the instructor, the students' summative assessment of their levels of understanding of the principal learning objectives are recorded. In the example shown, (Fig.6), a summative assessment is made of the seven digital system design objectives of the course shown in Fig.2. Clearly, in the ideal situation, the instructor's and students' assessments should be strongly correlated.

Summative Assessment (Program)

Other than prior accreditation by ABET, or by other like organizations, traditional summative assessment tools for engineering programs are hard to identify. This topic has fueled nationwide discussion, particularly among engineering department heads and college deans. Two assessment tools often referred to are national examinations: the FE (EIT) examination and the GRE. While extremely valuable indicators, each of these has serious limitations. The discipline-specific version of the FE exam has the enormously attractive feature of being able to provide any engineering program with a statistical breakdown of student performance in specific subject areas. In addition, it provides performance comparisons with both state and national averages. The problem with such comparisons is that not all engineering programs require their students to take this exam. In fact a recent survey[1] has suggested that only a small percentage of programs (approximately 15 %) actually do make such a requirement, making meaningful comparison difficult. Only in the (unlikely) circumstance in which students of a program that requires the taking of the FE exam achieve pass rates in excess of state and/or national averages does the FE exam become a valuable assessment tool. Another parameter further complicating this issue is the proportion of foreign students taking the exam. Since no program in the USA requires its students to pass this exam (a requirement that cannot be sustained legally), overseas students see little incentive in working to pass a grueling exam that has little meaning for them. Since percentages of overseas students in engineering programs vary enormously across the country, the results can be skewed significantly on this count alone.

In a similar way, not all engineering programs are geared to turning out large percentages of graduates seeking higher degrees. As such, the GRE exam is a valuable but fairly limited assessment tool. In any case, it is evident that these two exams really only match up to outcomes (a) and (e) of Criterion 3 (Fig.1).

Other conventional measures of summative assessment are mostly qualitative. Graduate employment rates are important but had to correlate with peer institutions. Conventional feedback from employers is, generally, in the form of letters of praise, commendation, etc.

Summative Assessment: Bringing the Students Aboard

Some reflection upon the issue of assessment quickly brings about a realization that active student participation is the key to the quantification of outcomes. This has been demonstrated above for formative assessment, but, given the aforementioned limitations of the FE and the GRE, the same is true for summative program assessment. It is therefore imperative that the student body be educated to understand that their active participation in the assessment process is a bridge to better learning.

Quantitative summative assessment can be formulated from data derived from three main sources: senior exit interview questionnaires, alumni surveys and employer surveys. The first of these should be carried out shortly prior to graduation (with the understanding that they are not evaluated until after submission of final grades). Once again, in the matter of comprehensive summative assessment, recording student perception of outcomes is indispensable. The outcomes (a), (b), (c), (d), (e), and (k), at least, of Criterion 3 (Fig.1) can be assessed quantitatively as part of exit interviews of graduating seniors, using numerical ratings in an extended questionnaire, a portion of one of which is illustrated in Fig. 7. The information derived from this kind of survey is crucially important, given that the student, at that moment can reflect back upon the Program in its entirety.

That student, as shortly as one year later, can actively participate in an alumni survey (Fig. 8) with a response flavored by his/her work experience. Accordingly, establishing a participative mindset among the student body should carry over when there is a mode change from student to alumnus/alumna. The style of this second survey is less specific but can be, instead, geared more to obtaining reliable information on the outcomes (f) through (k) of Fig.1 (which are clearly more difficult to measure). An upper useful limit on graduates' responses time is probably of the order of less than 5 years. Once the alumnus/alumna has been out of the Program for much longer than this, the influence of the Program is relatively insignificant in comparison with workplace influence.

While letters of recommendation from CEO's are undoubtedly impressive, the third survey, involving employers' responses, is most effective when the participant is in direct supervision of the alumnus. Here, again, therefore, it must be stressed that active student participation is a catalyst for alumni participation. A crucial element of the alumni participation is the identification of direct supervisors by name. Knowing these names, the employers' surveys (Fig. 9) can be quantitative in nature and (deliberately) attack the same points as those of the alumni survey (Fig.8).

Department of Electrical and Computer Engineering

EXIT QUESTIONNAIRE

Date__________________________ Major: EE _______ CpE _______

Semester Degree Completed____199____

Please rate the following using a scale of 1 through 10* (10 high)

1. Do you find that your education in the Department of Electrical and Computer Engineering has prepared you well for your career?

1	2	3	4	5	6	7	8	9	10	NA
__	__	__	__	__	__	__	__	__	__	__

2. Please evaluate the following areas:

	1	2	3	4	5	6	7	8	9	10	NA
Syllabus	__	__	__	__	__	__	__	__	__	__	__
General facilities	__	__	__	__	__	__	__	__	__	__	__
Faculty instruction	__	__	__	__	__	__	__	__	__	__	__
Advising	__	__	__	__	__	__	__	__	__	__	__
Course Sequences:											
EE321, 322	__	__	__	__	__	__	__	__	__	__	__
EE331, 332, 333	__	__	__	__	__	__	__	__	__	__	__
EE354, 355	__	__	__	__	__	__	__	__	__	__	__
Circuits lab (s)	__	__	__	__	__	__	__	__	__	__	__
Digital systems lab (s)	__	__	__	__	__	__	__	__	__	__	__
Electronics lab	__	__	__	__	__	__	__	__	__	__	__
Microproc. lab	__	__	__	__	__	__	__	__	__	__	__
Electromagnetics lab	__	__	__	__	__	__	__	__	__	__	__
T-lines lab	__	__	__	__	__	__	__	__	__	__	__
Energy Conversion lab	__	__	__	__	__	__	__	__	__	__	__
Textbook selections	__	__	__	__	__	__	__	__	__	__	__
Design content of courses	__	__	__	__	__	__	__	__	__	__	__
Departmental Computer facilities	__	__	__	__	__	__	__	__	__	__	__
Introduction to software packages	__	__	__	__	__	__	__	__	__	__	__
Math Instruction	__	__	__	__	__	__	__	__	__	__	__
Science Instruction	__	__	__	__	__	__	__	__	__	__	__
C/C++ Programming instruction	__	__	__	__	__	__	__	__	__	__	__
In-class team projects	__	__	__	__	__	__	__	__	__	__	__

Figure 7: Exit Interview Questionnaire

Department of Electrical and Computer Engineering
University of …

ALUMNI SURVEY

Name________________________________Date____________

Home Address:____

City:_________________State:___________Zip:_____________

Home Phone:_____________ Degree: EE____ CpE___

Semester Degree Completed:_________________Year:_______

Present employer:___________________Supervisor:_____________

Employer address:_______________________________________

Based upon your workplace experiences since graduation, how well do you feel your education at the University of South Alabama prepared you in terms of:

1) Oral communication skills:

1	2	3	4	5	6	7	8	9	10	NA
__	__	__	__	__	__	__	__	__	__	__

2) Written communication skills:

1	2	3	4	5	6	7	8	9	10	NA
__	__	__	__	__	__	__	__	__	__	__

3) Design skills:

1	2	3	4	5	6	7	8	9	10	NA
__	__	__	__	__	__	__	__	__	__	__

4) Computer/math skills:

1	2	3	4	5	6	7	8	9	10	NA
__	__	__	__	__	__	__	__	__	__	__

5) Technical/practical skills:

1	2	3	4	5	6	7	8	9	10	NA
__	__	__	__	__	__	__	__	__	__	__

6) Your ability to function as a team player:

1	2	3	4	5	6	7	8	9	10	NA
__	__	__	__	__	__	__	__	__	__	__

7) Your attitude towards life-long learning/keeping up-to-date:

1	2	3	4	5	6	7	8	9	10	NA
__	__	__	__	__	__	__	__	__	__	__

8) The way you deal with professional and ethical issues:

1	2	3	4	5	6	7	8	9	10	NA
__	__	__	__	__	__	__	__	__	__	__

9) Your overall ability to use techniques, skills and modern engineering tools in the workplace:

1	2	3	4	5	6	7	8	9	10	NA
__	__	__	__	__	__	__	__	__	__	__

Figure 8: Alumni Survey Form

University of …
Department of Electrical and Computer Engineering

Employer/Supervisor Survey

Company_________________________Representative_____________________

Date____

Based upon your experience with graduates possessing a BSEE/BSCpE from the Department of Electrical and Computer Engineering at the University of South Alabama, how would you rate them in regard to the following skills/traits on a scale of 1 through 10* (10 high).

1) Oral communication skills:
1 2 3 4 5 6 7 8 9 10 NA
— — — — — — — — — — —

2) Written communication skills:
1 2 3 4 5 6 7 8 9 10 NA
— — — — — — — — — — —

3) Design skills:
1 2 3 4 5 6 7 8 9 10 NA
— — — — — — — — — — —

4) Computer/math skills:
1 2 3 4 5 6 7 8 9 10 NA
— — — — — — — — — — —

5) Technical/practical skills:
1 2 3 4 5 6 7 8 9 10 NA
— — — — — — — — — — —

6) Ability to function as team players:
1 2 3 4 5 6 7 8 9 10 NA
— — — — — — — — — — —

7) Attitude to life-long learning/keeping up-to-date:
1 2 3 4 5 6 7 8 9 10 NA
— — — — — — — — — — —

8) Professional conduct in the work place:
1 2 3 4 5 6 7 8 9 10 NA
— — — — — — — — — — —

9) Overall job performance of our graduates under your direction:
1 2 3 4 5 6 7 8 9 10 NA
— — — — — — — — — — —

Figure 9: Employer/Supervisor Survey

Analyzing the Output of the Assessment Tools

Once each survey has been returned, the responses to each question in each survey can be averaged and then entered into an appropriate numerical matrix. Such matrices can be constructed as broad-based evaluation tools. Fig. 10 shows how (hypothetical) results of an employer survey may be correlated with ABET criteria. Similar correlation may be made with program objectives, departmental goals, or any other set of desired outcomes.

The composite score from this and other surveys can be entered into a master outcomes matrix (Fig.11) in which these and other entries may be averaged and used to determine the overall success in achieving desired outcomes (in this case, the eleven outcomes of ABET EC 2000 Criterion 3). It should be noted that the entries can be weighted. Clearly, such a methodology may be useful not only in identifying program weaknesses but also in validating educational innovation.

All of the instruments described herein are used to gather information to measure the success in achieving desired outcomes. This is an ongoing and dynamic process that is still in its earliest stages. Long-term success will depend greatly on motivating students to participate actively in the process both as students and alumni so that, over time, correlation between present indicators and future performance can be enhanced.

Employer Survey/ABET Criteria

Employer Survey Average	A	B	C	D	E	F	G	H	I	J	K
Question 1							7.7				
Question 2							8.2				
Question 3		7.4	7.4		7.4						
Question 4	6.8										
Question 5		6.4	6.4		6.4						
Question 6				8.1							
Question 7									8.8	8.8	
Question 8						7.0					
Question 9											7.5
Average	6.8	6.9	6.9	8.1	6.9	7.0	8.0		8.8	8.8	7.5

Index	
A	Ability to apply knowledge of mathematics, science and engineering
B	Ability to design and conduct experiments, as well as to analyze and interpret data
C	Ability to design a system, component or process to meet desired needs
D	Ability to function on multi-disciplinary teams
E	Ability to identify, formulate and solve engineering problems
F	Understanding of professional and ethical responsibility
G	Ability to communicate effectively
H	Broad education to understand the impact of engineering solutions in a global and societal context
I	Recognition of the need for, and an ability to engage in life-long learning
J	Knowledge of contemporary issues
K	Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Figure 10: Hypothetical Employer Survey Results

Master Outcomes Matrix											
Feedback Device	A	B	C	D	E	F	G	H	I	J	K
End-of-Semester Surveys											
Exit Interview Questionnaires											
FE Exam Results											
Alumni Surveys											
Employer surveys											
Local Industry Surveys											
Graduate School Admissions Rate											
Employment Rate											
GRE Results											
Accumulated Results											

Index	
A	Ability to apply knowledge of mathematics, science and engineering
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Figure 11: Master Outcomes Matrix

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References

[1] Johnson, Everett, (1998) Informal NEEDHA Survey.

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Martin R. Parker

Martin R. Parker received his B.S. degree from The University of Glasgow and his Ph.D. from The University of Salford, U.K. His research interests have been mainly in the field of magnetics, including magneto-optics, magnetic separation, and magnetoresistance. From 1990 until 1996 he was the M.I.N.T. Professor at The University of Alabama. Since 1996, he has been Chair of Electrical and Computer Engineering at The University of South Alabama.

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