AC 2008-316: CONNECTING THE DOTS IN ASSESSMENT: FROM COURSE STUDENT LEARNING OBJECTIVES TO EDUCATIONAL PROGRAM OUTCOMES TO ABET ASSESSMENT

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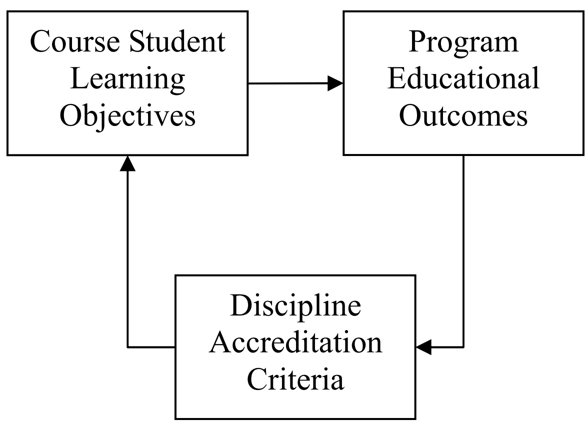
Connecting the Dots in Assessment: From Course Student Learning Objectives to Educational Program Outcomes to ABET Assessment

I. Introduction

The success of any institution of learning depends greatly on the students' engagement in their own education. Increased learning can be easily linked with increased engagement [1]. Increased engagement can be achieved in various ways, such as by associating students' interests and goals to class delivery, by encouraging students to work together, or by enhancing the student-professor relationship. Methods like these abound in the literature [2, 3, 4]. One method for verifying whether student learning has increased is monitoring the measurements of course learning objectives. The latter is the problem addressed in this paper. A method is proposed by which course learning objectives are assessed and further mapped into program specific educational outcomes, which in turn can help into quantifying assessment criteria set by accreditation boards and/or organizations. In this work we address specifically the needs of the Accreditation Board for Engineering and Technology (ABET) [5]. Graphically, this could be represented as follows:



Note that this paper concentrates in describing the method to go from course learning objectives all the way to discipline accreditation criteria. The final arrow is, of course, a key issue in assessment as the loop must be closed for assessment to really be useful.

The method presented in this paper provides a systematic way to measure and assess the achievement of course specific student learning objectives within the context of the educational program outcomes. Moreover, the paper includes the ***automation*** of measurable outcomes for program assessment, by connecting the outcomes to the course learning objectives. The method quantifies the contribution of each course towards assessing the achievement of the program educational outcomes. These outcomes are further connected to standardized assessment criteria provided by accreditation boards. A case study will be presented for the B.S. in Computer

Engineering Technology (CET) at Eastern Washington University (EWU). Expected benefits of the application of the proposed method are threefold:

1. Increased student ownership of learning objectives.
2. More cohesive and relevant set of class activities (i.e. tests, homework, laboratory experiments, projects, etc.).
3. A uniform program-wide way of assessing program outcomes against a set of accreditation criteria (i.e. ABET criteria).

The rest of the paper is organized as follows. The connection between course learning objectives, program outcomes and ABET criteria will be made in Section II. This section will also introduce the example summarily used throughout the paper. Section III will describe the method used to generate measurements and illustrate it continuing with an example begun in Section II. Finally, Section IV will summarize the contributions of the paper and present the concluding thoughts.

II. From Course Objectives to ABET Criteria

In following the global trend of globalization and quality control, ABET made inherent changes to the structure of its accreditation requirements. Some of these changes resulted in a set of criteria that need to be addressed by the program under scrutiny as a necessary step toward accreditation (please see http://www.abet.org for more detailed information). In the sake of clarity, these criteria are listed below and will be referred to in the rest of the paper.

An engineering technology program must demonstrate that graduates have:

a. an appropriate mastery of the knowledge, techniques, skills and modern tools of their disciplines,
b. an ability to apply current knowledge and adapt to emerging applications of mathematics, science, engineering and technology,
c. an ability to conduct, analyze and interpret experiments and apply experimental results to improve processes,
d. an ability to apply creativity in the design of systems, components or processes appropriate to program objectives,
e. an ability to function effectively on teams,
f. an ability to identify, analyze and solve technical problems,
g. an ability to communicate effectively,
h. a recognition of the need for, and an ability to engage in lifelong learning,
i. an ability to understand professional, ethical and social responsibilities,
j. a respect for diversity and a knowledge of contemporary professional, societal and global issues, and
k. a commitment to quality, timeliness, and continuous improvement.

Although the criteria are fixed, there is no formal method for assessing them. Furthermore, there are no lower limits nor any threshold, measurement or "number" attached to the criteria. Although at first instance this appears vague and loosely thought out, ABET purposely leaves enough space for programs to demonstrate *creativity* in their assessment methodology. Moreover, the necessity of including a continuous improvement component is made clear in no uncertain terms. Class assessment is only one component in the continuous improvement plan, but it is an important one, and is the only one addressed in this paper. More specifically, the intent is to operationalize the ABET criteria. In other words, variables are identified that allow expressing quantitatively the achievement of these criteria. However, *what* constitutes "achievement" needs to be determined. A grading scale must be decided upon for this. It is important to emphasize that raw numbers are meaningless unless compared (i.e. assessed) against a reference or metric. In the spirit of continuous improvement, the reference metric for each course will be the measurements obtained from the previous quarter (or semester) this method is applied. Conversely, the combination of all three quarters in the first academic year will provide the reference value for the assessment of program outcomes and ABET criteria. It is worth noting involvement from all faculty in an academic unit is of utmost importance for assessment to be useful to a program as a whole.

ABET requires class assessment to start with collecting samples of student work, i.e. keeping copies of all graded assignments of three students in *every* core and supporting course in the curriculum. These copies must extend through the six years prior to the visit from the ABET team. However this is only the beginning. Classes need to demonstrate a holistic coverage of the program educational outcomes, which in turn must be connected to the ABET criteria. This becomes overly complicated by the fact that no standards have been set by ABET. As a necessary first step the ABET criteria were matched to the already existing program educational objectives and outcomes for Computer Engineering Technology. For the sake or readability, the outcomes are not listed in this paper. Notice that outcomes must be chosen depending on program goals. A matrix is shown in Table 1 where the program outcomes are matched to the ABET criteria.

Table 1. Relation between CET program educational outcomes and ABET criteria *a – k*.

	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*
Outcome 1.1		*X*				*X*				*X*	*X*
Outcome 1.2			*X*								
Outcome 1.3		*X*	*X*								
Outcome 1.4	*X*		*X*			*X*			*X*		
Outcome 1.5		*X*	*X*							*X*	*X*
Outcome 2.1				*X*							
Outcome 2.2									*X*		
Outcome 2.3					*X*		*X*				
Outcome 3.1						*X*		*X*			
Outcome 4.1						*X*		*X*	*X*		

Reiterating what may be obvious, the nature of these outcomes are student oriented, that is, they are designed to verify what students are learning in their field. Moreover, an "outcome" in ABET lingo refers to the skills students gather at the end of their college career.

As an example, Outcome 1.1 for the CET program is detailed next.

> ***Outcome 1.1:*** *Students will demonstrate their ability to apply mathematics, science, engineering concepts and modern techniques and engineering tools to identify, formulate, model, and solve problems.*

The outcome clearly addresses ABET criteria *b, f, j*, and *k* (please see list above). Other outcomes were matched in a similar way. Note that in many cases there exist overlaps. For example, ABET criteria *b* is covered by outcomes 1.1, 1.3 and 1.5. Note that all outcomes already exist, and were developed by a department-wide committee.

The rationale behind the matrix in Table 1 is that if each of the program educational outcomes 1.1 through 4.1 are met, by deduction each of the ABET criteria *a – k* will be met as well.

Using the same logic, a connection can be made between the class learning objectives in each course and the program outcomes. As one example, let's take a class mandatory in the CET curriculum, say, Engr 250, the laboratory portion of Digital Logic. The course learning objectives published in the master course description for this course read as follows:

Learning Objectives and Corresponding Mapping to ABET Criteria:
Upon completion of this course, students will be able to:

1. Design a synchronous sequential logic circuit (Criteria (a), (c), (b), (e), (k)).
2. Test, interpret, evaluate, and optimize a digital logic circuit (Criteria (a), (b), (c), (e), (k)).
3. Explain and improve memory circuits (Criteria (a)).
4. Apply the ASM circuit design technique and RLT notation (Criteria (a), (b), (c), (e), (k)).
5. Design ripple and asynchronous counters (Criteria (a), (b), (c), (e), (k)).
6. Use registers for circuit design (Criteria (a), (b), (c), (e), (k)).
7. Identify and describe the different hardware families (Criteria (e)).

Note that as part of this work, each one of the CET curriculum's master course description was revised, so that course learning outcomes are congruent with ABET language. Each class' master course description should contain a similar set of learning objectives. Also it is worth mentioning that course learning objectives should be consistent with Bloom's taxonomy. A good reference on learning objectives design can be found in [6].

Back to the Engr 250 example. Easily, a matrix can be created that relates the contribution of this particular class to the *a-k* criteria. An example matrix, with a couple of courses in the CET program, is shown in Table 2. Following the work in [7], weights 1, 2, and 3 in Table 2 mean a given criteria is addressed "low", "medium", and "high," respectively. The reason behind the weights is that not all courses address a given criteria equally. For example, Engr 250 may be highly involved in the learning of design techniques, and therefore the application of mathematics and engineering concepts towards the solving of "problems." However, it also has a communication component that comes in the form of lab and project reports and in a final project formal presentation. It would not be accurate to portray the class as equally addressing design and communication. Thus, different weights are assigned to each one of them.

Table 2. Sample matrix for all classes with weighs for ABET's *a – k* criteria.

Course Number	EAC/ABET Criteria										
	a	b	c	d	E	f	g	h	i	j	k
ENGR 160 (Dig. CKT)	3		3	1	3		2	1			2
ENGR 250 (Dig. Hdwr)	3	3	3	2	3	1	3		1		3
⋮	⋮						⋮				⋮
⋮	⋮						⋮				⋮

Note that an equally easy correlation between course learning objectives and program educational outcomes 1.1 through 4.1 could have been made. However, ABET mandates that master course descriptions should be made in relation to criteria *a-k*. Moreover, another matrix including *all* courses in the program can be created to demonstrate that all ABET criteria are met by the combination of all these courses.

The relation *course learning objectives* → *program outcomes* → *ABET criteria* has now been established. Key concepts, however, have not been made apparent yet: What exactly constitutes a *met* objective? What is the number associated with a *met* objective? When can we say we have *met* a criterion? This is exactly the crux of the paper. Our intention is to generate a sample Excel spreadsheet that provides a way to incorporate all course learning objectives, assessment tools, and students' instructional evaluation and that automatically assigns a number (i.e. measurement) to each course learning objective. Furthermore, these numbers will automatically be matched to the respective program outcomes and ABET criteria. Each one of the steps will discussed next.

III. Obtaining Meaningful Measurements

A. Assessment of course learning objectives.

For the sake of uniformity, all measurements are normalized to a 0.0 – 4.0 scale (to emulate the existing GPA grading). The assessment of each one of the learning objectives is separated into two portions: performance and perception. The performance component relates to how well students performed, as a whole, in course assignments related to the given objective. An example for the assessment of course learning objectives is shown Figure 1.

Figure 1. Sample assessment for course objective one in Engr 250.

ENGR 250 -- Digital Hardware: Instructor and Student Course Objective Assessment																		
Quarter:	Winter 2007			Instructor:	Rodriguez-Marek													
			Course Embedded Assessment of Student Performance									Student Evaluation (%)						
Course Objective	Supported Criterion	Supprt'd Related Outcome	Assmnt Tool 6	Score (%)	Assmnt Tool 6	Score (%)	Assmnt Tool 6	Score (%)	Assmnt Tool 6	Score (%)	Perf. Comp.	E	G	A	P	NA	Stud Eval. Comp.	Total Composite
1. Design a synchronous sequential logic circuit.	a	1.1	Lab #3	70	Quiz 4	40	Hw 3, 4, 5	85			2.6	30	10	40	20		2.5	2.6
	b	1.2																
	c	1.3																
	e	1.4																
	k	1.5																

Continuing with the Engr 250 example started above, let's assume Laboratory Experiment #3 consisted in designing a particular synchronous sequential logic circuit, then the class average for this particular experiment will be one of the assessment methods for the course learning objective shown in Figure 1. Note that generally there will be several assessment methods for each particular course learning objective. The performance portion results from the average of all pertinent assessment methods, normalized to the aforementioned 4.0 scale. Note that typically selected problems from homework, exams, quizzes etc. are used for assessment. Data for the performance component must be compiled throughout the quarter, thus providing a clear idea of which student learning objectives are not been adequately addressed.

Note that it is not our intention to purport grades as the only method to assess the achievement of individual course learning objectives. Other student activities that will be planned, and can be used as measurements, are student portfolios, final project presentations to advisory board members, extracurricular projects supported by the department, internships, etc. However, the performance composite paints a "real-time" picture of how close we are to achieve a predetermined goal in a particular course learning objective.

It is important to understand that the assessment methods to be included in the performance portion of the spreadsheet must come from careful design of student assignments. Assignments turned in include, but are not restricted to examinations, homeworks, lab reports, quizzes, project reports, etc. The need to keep constant statistics of student performance results in assignments being much more thoughtful and, thus, more relevant for the student. Continuing with the example, here is a sample from the Engr 250 midterm examination in the Winter 2007 quarter:

> *This question addresses the following course learning objectives:*
> 1. *Design a synchronous sequential logic circuit.*
> 4. *Apply the ASM circuit design technique and RTL notation.*
>
> Problem #2. Draw the state diagram for a circuit that counts infinitely from 0 to 5. The circuit should count up (i.e. 0, 1, 2, etc.) when the input is 0. It should count down (3, 2, 1, etc.) when the input is 1. An *alert* output should turn on if there have been either three consecutive "up" counts or three consecutive "down" counts. Also, the circuit should be self correcting, that is, if any noise or interference sends it to an invalid state (i.e. 6 and 7), it should automatically correct to state 0. Any self-correction should reset the count-alert.

Note that each question in the test (and in all other assignments given to the students) is preceded by a paragraph that clearly indicates the related course learning objectives. The fact that such a statement is made generates more interest in the question, as it is directly applicable to an overall course objective. Eventually, an increase in ownership of the objectives should be seen. Of course, the statement serves the additional purpose of facilitating the inclusion of the data into the spreadsheet, and also provides uniformity throughout time. As always, there is a downside. In this case the extra time required to include prefaces to each question. Some faculty, however, may find it as a relief, since each assignment (or test, etc.) now provides more than a grade, rather, a direct feedback to the overall learning of students. It is worth noting that tests need not be the same from quarter to quarter, but they should address similar course objectives. For example, Problem #2 above will change the next time the class is offered. Students will be asked to do a completely new design, but the design will still address course objectives 1 and 4.

The second component is the perception component. The data for this component can only be compiled after the end of the quarter, as it comes from a survey to all students. The survey asks students to provide their perception on how well they believe they met each course objective. Let's go back to the Engr 250 example with course objective 1. Let's assume a 10 student class results in the following data:

3 (30%) students think they have a 4.0 ability to design a synchronous sequential logic circuit.
1 (10%) students think they have a 3.0 ability to design a synchronous sequential logic circuit.
4 (40%) students think they have a 2.0 ability to design a synchronous sequential logic circuit.
2 (20%) students think they have a 1.0 ability to design a synchronous sequential logic circuit.

Then the weighed average of the survey data will be:

Perception component = (30% × 4.0 + 10% × 3.0 + 40% × 2.0 + 20% × 1.0)/100 = 2.5

Thus 3.44/4.0 will be the contribution of the perception component to the total composite.

The total composite is the average of the perception and performance components. For example, if the average of all the assessments methods for course learning objective 1 (say Lab #3, Quiz #4 and Homework assignments 3, 4 and 5) in the performance component resulted in 65%, which in turn corresponds to 2.6/4.0, then the total composite for course learning objective 1 will be

Objective 1 composite = (2.6 + 2.5)/2 = **2.6**/4.0

Note that only one significant figure is shown to the right of the decimal point.

B. Assessment of program outcomes and ABET criteria.

A "score" now exists that directly assesses the achievement of each course learning objective. Using the ABET criteria corresponding to each one of the course learning objectives and the matrix shown in Table 1, another score can be obtained both for the *a – k* ABET criteria and for the 1.1 – 4.1 program outcomes. Let us emphasize that the point of the work presented in this paper is *not* to develop the correspondence among outcomes and learning goals, but the automation of the assessment process, which should ultimately reduce the time doing assessment and increase the time involved in the *application* of assessment towards improving student learning

The data from Figure 1 and Table 1 is used to generate a composite value for each of the Educational Program Outcomes. An example of how this is done is shown in Figure 2. Note that Figure 2 uses the values obtained in the "Total Composite" column from Figure 1. Further, although only one objective is shown in Figure 2 (for the sake of space and readability), the same is done for *all* program outcomes. Note that in coming up with the composite measurement for each educational program outcomes, we only include those course learning objectives that are related to the outcome at hand.

Figure 2. Sample calculation of assessment of program educational outcome for Engr 250.

ENGR 250 -- Digital Hardware: Course Assessment Tool											
EE Program Educational Outcome Assessment											
Instructor: Rodriguez-Marek		Quarter: Winter 2007									
Educational Program Outcome	Course Objective Total Composites (from "Objective" page)										
	1	2	3	4	5	6	7	8	9	10	Composite
1.1 Students will demonstrate their ability to apply mathematics, science, engineering concepts and modern techniques and engineering tools to	2.6	1.8	1.6	1.6	1.8	1.8	0.0				**1.6**

An Excel spreadsheet has been created that incorporates the necessary automation for the measurements originally obtained for the course learning objectives to be connected to the respective ABET criteria and program educational outcome. This numbers now show the contribution of a class to the program outcomes and ABET criteria, again in a 4.0 scale. Of course, *all* courses in the program must be combined to obtain the overall score for the *program*.

All the outcomes should be combined so that a measurement is generated for the a-k criteria, so that an output such as that shown in Figure 3 is produced.

Figure 3. Sample measurements of the contribution of one course to ABET *a – k* criteria.

ABET Criteria	a	b	c	d	e	f	g	h	i	j	k
Composite from Educational Program Outcomes	1.7	1.9	1.9	1.8	1.6	1.8	0.0	0.0	1.8	1.7	1.7

C. Program Assessment and Continuous improvement.

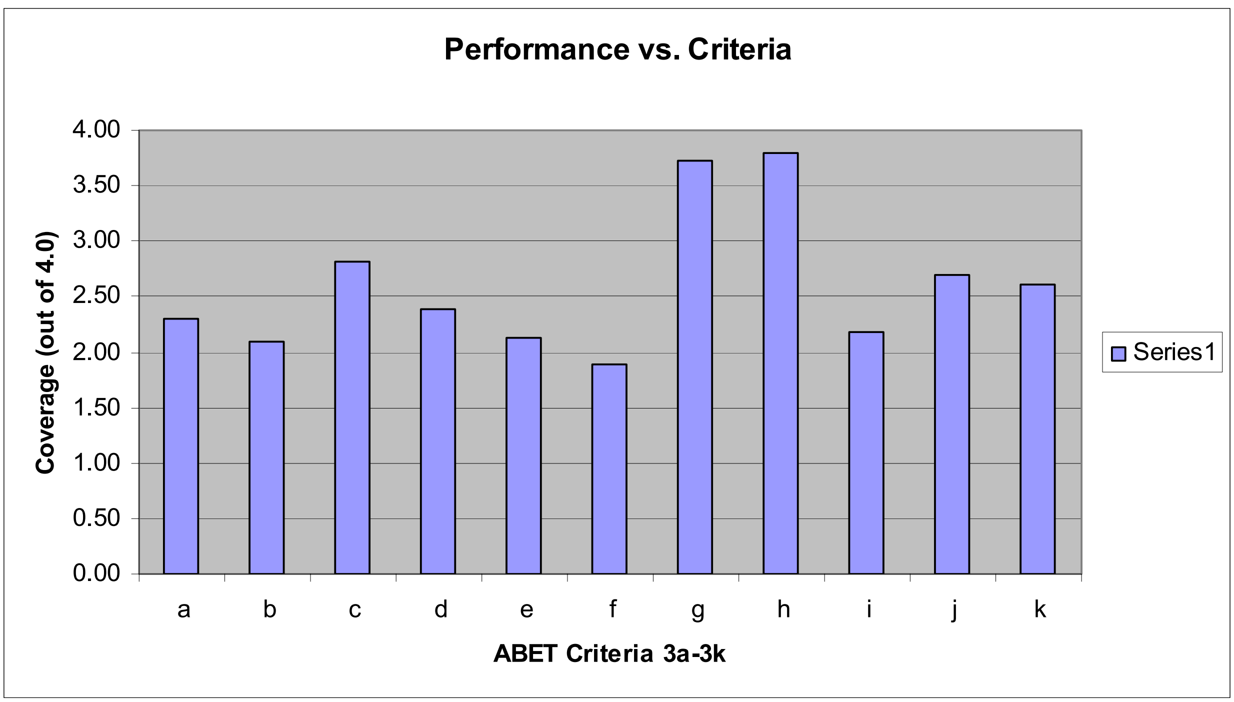
The overall score for the program is rather meaningless without a reference parameter. Is 3.5 our goal? Is 2.7? A "passing grade" is not provided by ABET. However, a comparison against ourselves is a good measure of improvement. Toward this goal, a continuous improvement plan that records the performance of each class in sequential manner can be generated. In this manner numbers become more meaningful, since they are now referenced against what has been done in the past. Pertinent information should also be included for increased relevance in the comparison: records of changes in class delivery, professors teaching the class, grading scales, etc. A yearly report should also be compiled detailing all these changes. Theses report are a living document to be referred to at all times when classes are taught. A quarterly course-wide assessment meeting is done by the faculty to assess quarterly classes. However, all data is further addressed in a yearly meeting, done at the end of the Spring quarter every year. The meeting is done to analyze assessment data. Further, this meeting decides what changes will be applied to specific courses and to the program as a whole. Note that all faculty in the program must use the forms generated as the end result of this project, thus providing uniformity in the assessment.

The final number for assessing ABET criteria will come from a compilation of the contributions from all individual classes with their respective weights, as shown in Table 2. An example of the calculation is in Figure 4.

Figure 4. Sample calculation of assessment of program achievement of ABET criteria.

Quarter		a	b	c	d	e	f	g	h	i	j	k
	ENGR 160 (Dig. CKT)	2.10	0.00	2.90	4.00	1.70	0.00	3.30	0.00	0.00	0.00	3.10
	Weigh	3	0	3	1	3	0	2	0	0	0	2
	Total/Class	6.30	0.00	8.70	4.00	5.10	0.00	6.60	0.00	0.00	0.00	6.20
W07	ENGR 250 (Dig. Hdwr)	**1.7**	**1.9**	**1.9**	**1.8**	**1.6**	**1.8**	**0.0**	**0.0**	**1.8**	**1.7**	**1.7**
	Weigh	3	3	3	2	3	1	0	0	1	0	3
	Total/Class	5.12	5.68	5.63	3.68	4.73	1.84	0.00	0.00	..	0.00	5.20
S06	ENGR 260 (Microcontrollers)	**3.10**	**3.20**	**3.00**	**0.00**	**3.10**	**0.00**	**3.75**	**0.00**	**3.30**	**3.30**	**3.12**
	Weigh	3	3	1	0	3	0	1	0	0	1	2
	Total/Class	9.30	9.60	3.00	0.00	9.30	0.00	3.75	0.00	0.00	3.30	6.24
	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	ENGR 440 (Dig. Com)	0.00	1.20	3.60	2.20	0.00	1.90	4.00	3.80	2.90	2.50	2.84
	Weigh	0	3	3	3	0	3	3	3	3	3	3
	Total/Class	0.00	3.60	10.80	6.60	0.00	5.70	12.00	11.40	8.70	7.50	8.52
	Totals	2.30	2.10	2.81	2.38	2.13	1.88	3.73	3.80	2.18	2.70	2.62

Note that the totals are all in a 4.0 scale, which can be converted into a bar graph for easier analysis:



The threshold for each of the criteria may be set independently, however that is beyond the scope of this paper. Note that a year-by-year graph of individual ABET criteria can be easily generated.

D. Spreadsheet Automation and Future Work

As it stands, a template exists that needs minimum input from faculty prior to utilization in a given class. The information that needs to be input is the following:

a. Class name.
b. Class number.
c. Quarter it is being taught.
d. Instructor's name.
e. Course learning objectives.
f. Assessment methods.
g. Performance grades.
h. Perception survey results.

The spreadsheet then computes the necessary measurements.

One downside with the current assessment methodology is that it does not take assessment methods other than what is done in the classroom as part of the final measurement that results from the automated spreadsheet. The authors are currently investigating methods to parameterize other activities. Some of these are listed next, separated as course specific and program wide activities.

A. *Course specific*

a. *Focus groups.*
   Focus groups could be run one or more times during a quarter based entirely on the achievement of course student learning outcomes. Faculty should provide the means for candid exchange of ideas.

b. *Project presentations to other faculty and to members of the industrial advisory board.*
   Classes with final projects (many classes in the CET degree) would make final projects' presentation open to all faculty members and students in the department. Advisory board members would also be invited to these presentations. A similar system is currently available for Senior Capstone presentations. Some planning from the faculty would easily allow for one day in the week before finals to be reserved for department wide presentations. This would also help lower class students to catch a glimpse of what is done by the upper class students. An added benefit would be the expectation generated by what is yet to come in the curriculum.

c. *Mentor and faculty evaluations from internships.*
   Work done in internships could be related to class material and also related to student learning assessment and/or program outcomes and ABET criteria.

B. Across courses

d. Student portfolios

Student portfolios are already collected, however they are rarely used. Various discussions have been conducted among faculty about how to use these data, and assessment is what is generally accepted as the best solution. Although these portfolios are hard to use for course specific learning objective assessment, they could come in handy in assessing educational program outcomes.

e. Department-sponsored extracurricular projects.

Several projects are typically done by teams of students with common interests. The main catalyst for these projects is the EWU Student Branch of the Institute of Electrical and Electronics Engineers (IEEE). A sample project currently in development is a maze-solving autonomous robot for the IEEE Micromouse competition. Such projects could provide important insight into how some program educational outcomes are being met.

f. Focus groups.

Program-wide focus groups could be done just as course specific focus groups, but this time across several courses and classes. Such a focus group would be insightful to determine the achievement of program outcomes.

g. Exit surveys.

In a similar way to the focus groups in *(f)*, exit surveys would generate more data to use in the assessment.

IV. Conclusions

The paper described above intends to provide a systematic and unified methodology to monitor the achievement of student outcomes both throughout the quarter and in a year-by-year timeline. The automation through Excel spreadsheets allows faculty to easily monitor the class performance literally as new data is input in the system. The availability of a convenient mechanism for assessment allows faculty to spend less time doing assessment, and more time analyzing the results to improve the class itself.

There is one noticeable downside: the method proposed requires significant class planning up-front and a mature commitment to assessment by the faculty teaching the class. However, once this initial step is overcome, the benefits of the product easily outweigh the cons. The CET program is required by ABET to maintain a rigorous continuous improvement plan. The automation hereby presented has represented significant time savings to the faculty in the long term. Moreover, a uniform class and program assessment methodology is in place that can be used in a sustainable and systematic manner. It is worth noting that the ABET assessment team that evaluated our program praised our spreadsheets as an extremely useful tool. As a final note, it is important to emphasize that after the initial first year work was completed, the time needed to be spent conducting assessment diminished greatly. Faculty finally can obtain useful data, while at the same time fulfilling ABET's continuous improvement needs.

V. Acknowledgement

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