Examples of Rubrics Used to Assess ABET Student Outcomes in a Capstone Course

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Introduction

In our Electronics Engineering Technology (EET) program, we are continually re-evaluating the student outcomes and how they are measured by the assessment process. We have defined, with the approval of alumni and our industrial advisory board, sixteen Student Outcomes labeled (a) - (p). These begin with the ABET Criterion 3 Student Outcomes (a) - (k)[1] , and then add the Program Criteria for Electrical/Electronics Engineering Technology, and some university required student learning outcomes, which are labeled (l) - (p). ABET requires at least one evaluation of each student outcome at some point in the program, preferably toward the end of the curriculum. We have chosen to do most this evaluation in the Project Management/Capstone two-semester course sequence. In the first semester, students learn the theory and basic practices of project management, and also define, plan and begin their capstone project. In the second semester they complete their group project. Most of the program's learning outcomes are assessed using direct measures from evidence of student's project work, with a few assessments coming from the student's opinions of their own progress, an indirect measure. What we are concerned with is how to evaluate the direct evidence of student work, that is, "grading" the student's progress on meeting the assigned learning outcomes.

Almost all evaluation at the level of a program's Capstone course is subjective, as the course deals with how well the student project groups can define and solve a technical problem, not an objective measure such as whether the students know a fact or not. We have found that keeping track of all the evidence of student learning, and doing as objective as possible evaluation of the student's work, requires the use of standardized rubrics.

Rubric Rationale

Rubrics can be defined as descriptive scoring schemes that are developed by teachers or other evaluators to guide the analysis of the products or processes of students' efforts[2]. The use of a rubric is more likely to provide meaningful and stable appraisals than are traditional scoring methods. Assessing student's knowledge and skills on the basis of a scale offers several advantages. First, it presents a continuum of performance levels, defined in terms of selected criteria, towards full attainment or development of the targeted skills. Second, it provides qualitative information regarding the observed performance in relation to a desired one. Third, its application, at regular intervals, tracks the student's progress of his or her skill mastery[3].

The scoring scale used on a rubric does not have to follow only one pattern. For our program, we mostly use a scale of 10 (high) to 1 (low) on many of our overall scoring rubrics, where we are following a 90% = A, 80% = B, etc., grading scale. Simon describes their process of developing a scale. In the first version, the scale is developed around the expected student performance at the level of excellence. As the course progressed, examples of performance at

each level are identified and used to refine the scale. Scoring occurs when the faulty identifies, within the scale, and for each criterion, a description that most closely matches the observed performance. When the faculty use the rubric to assess student work, they can compare the identified or observed performance level to a predetermined standard level[3]. Many other rubrics will have just three or four different levels of measure, as will be demonstrated below.

Another definition of a rubric is that it is a scoring tool that is generally used for subjective and authentic assessments. In subjective assessments, rubrics help create a certain level of objectivity. As a result, learners are clearer about the expectations prior to assessment and are clear about their areas of weakness and strength after the assessment. In authentic assessments (which are usually subjective), rubrics help educators communicate and assess levels of performance[4].

Rogers writes that data collection activities must be examined in light of good program assessment practice, efficiency, and reasonableness[5]. The National Academy of Engineering in 2009 issued a report called "Developing Metrics for Assessing Engineering Instruction: What Gets Measured is What Gets Improved". In that report they reinforce the concept that a sustainable evaluation system must not require implementation that is burdensome to faculty or administrators. Using rubrics for assessment standardizes the evaluation of the assessments, and reduces the burden on faculty time[6].

Rubrics can be used at three different phases of an assignment: pre-assessment, assessment, and post-assessment. In the pre-assessment phase, rubrics can be used to communicate expectations with students; hence, giving them clear directions and helping them avoid confusions which usually hinder their learning. During the assessment phase, rubrics are used to allow for more easily scoring the assignment. After a rubric is scored, the scored-rubric is given back to students to communicate, summatively, their grade and formatively, their weaknesses and strengths[4].

Rubric Categories and Examples

Traditional education research breaks rubrics into two main categories, analytical or holistic. The rubric in Figure 1 is an analytical, also considered a quantitative, rubric. Analytic rubrics are usually preferred when a fairly focused type of response is required[7]. This example is used as an objective measure, from a test, of how well students learned project management definitions and basic skills such as developing a CPM Chart. In the figure, as we will do for most the rubric examples below, we define which specific ABET student outcome that this rubric helps measure.

ABET Outcome	Tool	Superior 10	Excellent 9	Good 8	Fair 6-7	Poor 0-5
(n) the ability to apply project management techniques	Midterm Test	100% on exam	90-99% on exam	80-89% on exam	etc.	

Figure 1 Analytical Rubric

Holistic, also considered qualitative, rubrics are used to evaluate or assess the whole process, performance, or product. Although holistic rubrics contain a scale and criteria, their use is such that the element under investigation is given one score for the entirety of the performance. This

type of rubric is predicated on the idea that instructors "know quality when they see it"[8]. Further, the use of holistic rubrics is probably more appropriate when performance tasks require students to create some sort of response and where there is no definitive correct answer[7].

Mertler suggests that for holistic rubrics, the faculty should write thorough narrative descriptions for excellent work, down to poor work, incorporating each attribute into the description[7]. Figure 2 shows a holistic rubric used for measuring teamwork, which is a highly subjective thing to measure. The rubric attempts to use descriptive labels to help the course instructor be able to rate student teamwork more objectively.

ABET Outcome	Tool	Superior	Excellent	Good	Fair	Poor
		10	9	8	7-6	5-0
(e) an ability to function effectively as a member or leader of a team	Rubric at middle and end of project	Completes all assigned tasks by deadline without prompting Work accomplished is thorough, comprehensive, and advances the project Proactively helps other team members complete their assigned tasks to a similar level of excellence	Completes all assigned tasks by deadline Work accomplished is thorough and advances the project Works with other team members as required.	most tasks mostly through only with prompting	some tasks does not advance only on some tasks	few tasks little work accomplished works poorly with team members

Figure 2 Holistic Rubric Example

Figure 3 is another holistic rubric. This particular assessment is done after the course is complete and grades are given, and the course instructor can be more objective about scoring, and does not have to worry about student reaction to a grade.

ABET Outcome	Tool	Superior	Excellent	Good	Fair	Poor
		10	9	8	7-6	5-0
(p) the ability to analyze, design, and implement industrial control systems or computer network systems	Final Report	Design process completely detailed All appropriate supporting documents present in written report Clear understanding of design process demonstrated	Mostly detailed Most Mostly clear	Basically detailed Some Some-what clear	Sketchily detailed Few Little	Not detailed No Poor

Figure 3 Portion of Final Report Rubric

The next example, Figure 4, can also be called a holistic rubric. The rubric is used for the several status reports generated during the course of the project, and also for the final report.

ABET Outcome	Tool	Superior 10	Excellent 9	Good 8	Fair 6-7	Poor 0-5
(k) a commitment to quality, timeliness, and continuous improvement	Status Reports and Final Report	Reasons with all good/correct results and/or interprets data very well. Develops exemplary conclusions based on results.	Reasons with mostly good/correct results and/or interprets data well. Develops good conclusions based on results.	Reasons with some good/correct results and/or interprets data somewhat well Develops some good conclusions based on results.	Reasons with minimal good/correct results and/or interprets a small amount of data well Develops minimal conclusions based on results.	Reasons with poor results and/or interprets data poorly Develops poor conclusions based on results.

Figure 4 Holistic Rubric

Holistic rubrics can include examples of work that meet each level of the rubric[8]. In the capstone project the groups must be able to summarize why an organization would pay them to do this project, which we call the Project Justification Statement. Figure 5, in which the actual text of the examples is removed for space reasons in this paper, gives a qualitative description and quantitative number to each example. The students see this rubric before they begin their work.

0 pts. Way too short	Example – 1 sentence
1 pt. Too short	Example – 2 sentence
2 pts. Better – includes numbers & graph	Example – paragraph & graph
3 pts. Nice numbers, but no explanation	Example – table of numbers only
4 pts. Almost good enough	Example – several paragraphs
5 pts. (Few groups achieve this in the first pass)	No example given, so groups don't just copy the good example

Figure 5 Project Justification Statement Rubric

Rubrics can also be categorized as either formative or summative in nature. Formative assessments are usually administered in the classroom, and are used as feedback to improve teaching and learning. Examples include teacher's feedback on work in progress, such as drafts of papers or preparations for presentations. Summative assessments measure what students have learned at the end of some set of learning activities, such as teacher-made tests at the end of the year[9].

An example of where we use a formative rubric in our program is close to the beginning of the capstone project. In class, in the project groups, the students are asked to do the following exercise of three steps. There is no grade given, but the feedback from the course instructor, using the rubric, helps the groups to begin to plan their capstone project. The results of this rubric, Figure 6, are used as a part of the overall assessment of ABET (f) an ability to identify, analyze, and solve broadly-defined engineering technology problems.

1. Brainstorm and come up with tasks that must be done for your project. Don't limit yourself to putting them in order to start. Just think of tasks that must be done to complete your project. There is a time limit of 5 minutes.
2. Add some detail to the tasks, as needed. 15 minutes.
3. Put the tasks in order, using yellow Post-Its to indicate a time order. 5 minutes

Brainstorming Rubric	4 pts Exceeds Expectations	3 pts Meets Expectations.	2 pts Nearly Meets Expectations.	1 pts Below Expectations.
Quantity of tasks How many tasks have you considered?	> 20	10 – 20	5 – 10	< 5
Variety of ideas Is there are a wide variety of tasks indicated?	There is a very wide variety of tasks indicated	There is a variety of tasks indicated	There is a little variety of tasks indicated	There almost no variety of tasks indicated
Depth of Detail Are tasks supported with detail?	All tasks are well supported with many details.	Most tasks are well supported with many details.	Some tasks are well supported with some details.	Few tasks are supported with few details

Figure 6 Formative Brainstorming Assignment & Rubric

The rubric following, Figure 7, is used on the final report. It is classified as a summative rubric, because it is only assessed at the end of the course.

ABET Outcome	Tool	Superior 10	Excellent 9	Good 8	Fair 6-7	Poor 0-5
(m) the ability to locate, organize, critically evaluate, and effectively use information from a variety of sources	Final Report	Very well researched, excellent sources	Well researched, excellent sources	Well researched, good sources	Fair research, fair sources	Poorly researched, poor sources

Figure 7 Summative Rubric

The following summative rubrics, Figure 8, are used to assess student essays on what can be termed the ABET "Professional Skills"[10] outcomes. These are qualitative in nature and highly subjective. The assessments of, and rubrics for, these student outcomes are most in need of improvement in our program.

ABET Outcome	Tool	Superior	Excellent	Good	Fair	Poor
(i) an understanding of and a commitment to address professional and ethical responsibilities, including a respect for diversity (j) a knowledge of the impact of engineering technology solutions in a societal and global context	Essay assignment	Complete demonstration and understanding	Thorough demonstration and understanding	Basic	Little	Poor

Figure 8 ABET Professional Skills Rubrics

The Design Review is an important professional fact of life in the field of engineering and engineering technology practice. In our program we use it when there is a little less than two months to finish the project. The students are given this rubric to see, Figure 9, to help them prepare the appropriate material for the review. The review is done by a panel of faculty, including the Capstone course instructor, the faculty technical advisor, and other Engineering Technology faculty who are not associated with the project. This type of rubric is summative in nature, in that they are given a grade that is a significant part of the semester grade, essentially on the quality of the project work done to that point. But the assessment is also formative, as students use the feedback that they receive, most often from the independent faculty representatives, to improve their project work.

Design Review Rubric	**4 pts** Exceeds Expectations	**3 pts** Meets Expectations.	**2 pts** Nearly Meets Expectations.	**1 pts** Below Expectations.
Up-to-date Status Report, Customer Reviews, Tracking Gantt	X	Present	X	Not present
Deliverables Table - show what has been finished	X	Present	X	Not present
All documentation that you have to date on what you have done technically on the project.	Documentation is all clear, complete, and organized	Documentation is mostly clear, complete, and somewhat organized	Documentation is clear, but not complete or organized	Documentation is not clear, incomplete, and is disorganized
Hardware and/or software of project to date	Project works as plan describes, is almost ready for final version	Project works to some extent, it is clear what works needs to be done in next few weeks	Projects works somewhat, but it is unclear what work still needs to be done	Project does not work, work needed to complete is unknown
If you need to change your plan / scope of the project / deliverables, etc., in order to complete the project by Apr. 15, write that out and make it as clear as possible	Plan is Very Clear	Mostly clear	Somewhat unclear	Unclear

Figure 9 Design Review Rubric

Oral presentations are done at a Senior Design Conference sponsored by the College of Engineering late in the first semester, and again to the entire Capstone course student population, and sometimes underclassmen in EET, at the end of the project. This is used to help assess ABET (g) an ability to communicate effectively regarding broadly-defined engineering technology activities. Figure 10 shows the rubric used, which evaluates both the individual's speaking skills, and the group's PowerPoint and organizational qualities. In the first semester, this provides a formative feedback; whereas at the end of the project it is a summative evaluation.

Individual Presentation Skills	Superior	Excellent	Good	Fair	Poor
1. Speaker had appropriate volume of speaking voice.	5	4	3	2	1
2. Speaker did NOT exhibit nervous habits.	5	4	3	2	1
3. Speaker made eye contact with audience	5	4	3	2	1
4. Speaker used visual aids well.	5	4	3	2	1
6. Speaker had a thorough understanding of the material	5	4	3	2	1
Presentation Content and Quality – Group – all in group have same score for this					
1. Group followed prescribed guidelines.	5	4	3	2	1
2. Group had appropriate amount of information.	5	4	3	2	1
3. Group had easy to follow visual aids.	5	4	3	2	1
4. Group had organized, concise, and relevant information.	5	4	3	2	1

Figure 10 Oral Presentation Rubric

As we have developed rubrics over the years, we find some do not fit in the categories mentioned above. We define the following rubric, Figure 11, as a record-keeping or checklist rubric. Moskal defines checklists as an appropriate choice for evaluation when the information that is sought is limited to the determination of whether specific criteria have been met[11]. The course instructor is determining if the project group is updating their project status on a webpage as the project is on-going, and not necessarily assessed the quality of the information posted. Not all items are present from the beginning of the project, so the rubric sections are added as needed. The figure is condensed to show all the items that are present at the end.

Project Name	Date Assessed			
These items are evaluated in the Formal Project Proposal – just need to be present				
Title Block, Abstract, Charter, Formal Project Proposal, PowerPoint from Conference	Present - 1	Not Present - 0		
Need to be updated during project. If an item is not needed for this project, or is not required to be done yet, do not score it				
Reports: Gantt Chart, Customer Reviews, Status Reports, Deliverables Table, Justification Statement	Excellent – 3 Updated on schedule	Good – 2 Missed 1 update	Fair – 1 Missed 2 or more updates	Not Present - 0
Technical Information: System Diagram, Links to similar projects, Pictures/drawings, Circuit schematic, Links to spec sheets, Enclosure drawings, Parts list w/ Costs, Software listings, User's Manual	Excellent - 3 Up to date – matches project status	Good - 2 Behind by 1 date/ revision	Fair - 1 Behind by 2 or more	Not Present - 0
Total - % of possible points				

Figure 11 Project Webpage Status Rubric, condensed

The project webpage rubric is one that the author has modified and changed the most of any rubric used in the Project Management / Capstone course sequence over the years. Mertler says that you should be prepared to reflect on the effectiveness of the rubric and revise it prior to its next implementation[7]. It does not help retain consistency of scores from year-to-year, which your program may want as you document your continuous improvement efforts, but it is often necessary.

In our EET program we have found that groups write better final reports when the group has been keeping their webpage information updated well[12]. We use this rubric as a part of our assessment for ABET (o) the ability to use appropriate engineering tools in the building, testing,

operation, and maintenance of electronic systems.

Another checklist type rubric is shown in Figure 12. There are many different sections to evaluate on the Formal Project Proposal and the Final Report, which take place near the beginning and the end of the project. Both students, as they writing their report, and the course instructor, when grading, can check to see if that part of the report is present. Within each checkbox, without listing levels of excellent, good, etc., the course instructor will give a point value less than max if that section is less than acceptable. Then, the comment section is needed to further elaborate on why this score was given, and can record the quality of that section. This is used mostly as a summative evaluation, but students are given a chance to re-write the formal proposal, correcting shortcomings that are pointed out, in order to improve their score. This rubric makes it fairly easy to assign points and give a grade. The results of this rubric are used as a part of the overall assessment of ABET (p) the ability to analyze, design, and implement industrial control systems or computer network systems.

Section	**Points**	**Sections**			**Comments**
On time?	-10/wk.				
Title Page	2				
Sec. I Exec. Summary	3	One page?	Completely describe?		
Sec II. Charter	10	Objective?	Customer & needs?	Resources?	
		Priorities & Constraints?	Deliverables?	System Diagram?	
		Budget?	Matches WBS?	Report dates?	
Sec III. Description	30	Objective?	Long description?	Deliverables as a table?	
		System diagram?	Technical reqmts?	Limits & Exclusions?	
		Justification?	Cust Review?	Status Rpts?	
Sec IV. Matrix	5	Graph?	Descriptions?		
Sec V. WBS	30	Numbered?	Descriptions?	Person responsible?	
		Time Estimate?	Actual costs?	"As done" labor costs?	
Sec VI. Gantt	20	Same as WBS?	Separate Reports and Project tasks?	Baseline?	
		Neat, readable?	Times identified?		
Total	100	Additional Comments			

Figure 12. Formal Proposal/Final Report Rubric

One point of concern that comes up in a group project is how to measure, within the team, the individual student's contribution. The following two rubrics, done by the faculty technical advisor of the project team at the end of the project, attempts to do so. First, the group is given a rating for each of these seven ABET assessment points. Figure 13 shows the first half of this holistic, summative rubric. Wording to help define what is Superior, Excellent, etc., for each of these ABET points is hard to define. In our program, we have gone back and forth between just using a 1 – 10 scale, and using specific descriptions for each level, as we do in other rubrics. At this time we are just using the numerical scale, but that may change in the future.

Technical Advisor Rating of Project Team Members	
Group	
Using a 1 – 10 scale, with 10 being the highest score, please rate the project group for these EET ABET Assessment points. If you cannot score an area, because you did not observe this, please use N/A	
ABET n) Demonstrate the ability to apply project management techniques (Overall – how did the project turn out?)	
ABET d) Demonstrate ability to design systems, components, or processes for broadly-defined engineering technology problems appropriate to program educational objectives	
ABET e) Demonstrate an ability to function effectively as a member or leader on a technical team	
ABET f) Demonstrate an ability to identify, analyze, and solve broadly-defined engineering technology problems	
ABET k) Demonstrate a commitment to quality, timeliness, and continuous improvement	
ABET o) Demonstrate the ability to use appropriate engineering tools in the building and testing of electronic systems	
ABET p) Demonstrate the ability to analyze, design, and implement industrial control systems or computer network systems	

Figure 13 First part of Technical Advisor Rubric

The faculty technical advisor is then asked to rate the students individually, using the rubric seen in Figure 14. This is an overall rating; the faculty as a group agree that it would not be possible to rate each student individually on each of the seven ABET assessment points. The terms used here are qualitative in nature, as that is felt to be fairer than a strict quantitative number. The Capstone course instructor changes the qualitative rating to a quantitative value in order to record and report values. The numbers used are from Excellent = 10, Very Good = 9, down to Superficial = 4 and No Show = 0. The average score of the seven ABET assessment points is then multiplied by the individual students rating to give the student a score. It is felt that individual student effort makes up a large part of the team effort.

Individual	
Please rate the degree to which each member fulfilled his/her responsibilities in completing their assigned tasks. These ratings should reflect each individual's level of participation, effort, and sense of responsibility, not his or her academic ability. The possible ratings are as follows:	
Excellent	Consistently went above and beyond – helped teammates, carried more than his/her fair share of the load.
Very Good	Consistently did what he/she was supposed to do, very well prepared and cooperative.
Satisfactory	Usually did what he/she was supposed to do, acceptably prepared and cooperative.
Ordinary	Often did what he/she was supposed to do, minimally prepared and cooperative.
Marginal	Sometimes failed to show up or complete assignments, rarely prepared
Unsatisfactory	Consistently failed to show up or complete assignments, unprepared
Superficial	Practically no participation
No show	No participation at all

Figure 14 Second part of Technical Advisor Rubric & Student Self-Assessment

Students are given a chance to rate their own team, both at the end of the first semester, and then again at the end of the project. They get the same rubric rating form as the technical advisor does, Figure 14, with the instructions to "Please write the names of all your team members, including yourself, and rate the degree to which each member fulfilled his/her responsibilities in

completing their assigned tasks." Again, they are not given a quantitative scale, but the more general qualitative scale to use, in the hope that they will be more accurate in their evaluation.

Students also rate themselves at the end of the Capstone course, which is the end of their undergraduate education, with this survey, Figure 15. This is not technically a rubric, but the form provides the program with good summative feedback. The results of the survey provide an additional element, an indirect measure, to add to the assessment of all the ABET student outcome assessments that are done directly.

ABET Student Outcomes		Very Confident or Satisfied	Somewhat Confident or Satisfied	Neutral	Not Confident or Unsatisfied	Very Unconfident or Unsatisfied
(a)	ability to select and apply the knowledge, techniques, skills, and modern tools of their disciplines to broadly-defined engineering technology activities	5	4	3	2	1
etc.						
(p)	ability to analyze, design, and implement electronic systems	5	4	3	2	1

Figure 15 Student Self-Assessment Survey

Summary

RCampus, a website set up as a collaborative learning environment, where faculty can share and discuss rubrics, makes these statements about the expectations and benefits of rubrics[4]:

- Clarify constraints with students, colleagues, other evaluators, administrators, and yourself.
- Communicate expectations with students: A rubric tells students what is expected of them, the grading criteria, what counts and what doesn't, how many points they will earn for each task, and how their work is graded.
- Bring objectivity to subjective scoring.
- Easy scoring and recording of it.
- Communicate grades with students: A graded rubric helps students understand how they were graded and what their areas of strength and weakness are.

If you, as a faculty member, are developing your own rubrics, Rocco[8] suggests these guidelines:

- Outline your expectations.
- Divide expectations into traits for a quality performance or product.
- Decide on a hierarchy of traits.
- Decide on the rubric format.
- If you are using a holistic rubric, create sample products for each level of competence.
- Share and discuss the rubric with students.
- Use the rubric.
- Modify the rubric as needed.

We use rubrics consistently in our EET program, but as we go through our continuous improvement process, we often see that the rubric we are using is measuring the wrong aspects of what we want, or is the wrong kind of rubric. We continually are reassessing how we measure student progress.

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