Using Rubrics to Evaluate Engineering Design and to Assess Program Outcomes

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Abstract

It has been suggested that all faculty who teach in an engineering program can use rubrics to consistently assess students and simultaneously use that rubric to assess program outcomes for continuous improvement. MSOE is working to develop such rubrics to directly measure student performance and assess outcomes of ABET Criteria Three and Four. One of those rubrics was used to assess student performance in MSOE's four-year design process. The intent was to give a direct measurement that could be used to assess program outcomes. This paper describes the development and application of a rubric for engineering design and the difficulties encountered with that rubric. While difficulties were encountered, the MSOE biomedical engineering faculty believe rubrics will produce consistent results that can be used to improve its design courses and the curriculum.

Introduction

Although referring to pornography, in 1964, Justice Potter Stewart stated "I know it when I see it." That is often the belief of faculty members who are assessing student performance. When a faculty member is asked about the quality of a students work, most faculty will say "I know it when I see it;" but to one a symphony to another noise. The biomedical engineering faculty at Milwaukee School of Engineering (MSOE) are working to develop rubrics to directly measure student performance and to simultaneously assess program outcomes for their four-year design course. Their hope is to avoid the "I know it when I see it" argument and finely tune the orchestra.

A process is suggested by Blanchard whereby faculty who teach in an engineering program can use a rubric to consistently assess students and simultaneously use that rubric to assess program outcomes for continuous improvement.[1] The faculty at MSOE plan to apply this approach and to use their assessment results for student performance assessment and for continuous program improvement. Although the rubric presented by Blanchard is applied to a course that has outcomes defined for a single semester course, the MSOE faculty believe that this process could be applicable to MSOE's four-year design process. It is expected that this assessment will give one of the corners of triangulation for assessing program outcomes. Other corners include the FE examination and common final examinations across the curriculum. This paper presents one of the MSOE rubrics and describes when and how it is used.

Background

ABET Criterion Four; Professional Component; requires that "Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints." Additionally, ABET Criterion Three; Program Outcomes and Assessment; requires that students have "an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability."[2] Based on these criteria, there must be an assessment process in place to demonstrate that students have this ability and that the program is using that assessment to improve the curriculum.

The faculty at MSOE have been assessing a student's ability to design a product, system, or service based upon "knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints" as defined in and by ABET Criteria Three and Four. However, the MSOE faculty believe that a student more thoroughly practices and achieves the design experience if that experience is extended throughout their undergraduate years rather than in a single year or a single semester.[3,4,5] Additionally, the MSOE faculty have shown how the four year design program can be used to assess student achievement of program outcomes.[3,4,5] However, there is still work that must be done to incorporate that assessment in the continuous improvement of the Biomedical Engineering program at MSOE.

In order to meet ABET's design requirement, the experience must be open-ended resulting in "open-ended" assessment data. There are both advantages and drawbacks to assessing open-ended data. The advantages are that it can yield rich information about if students' are achieving program outcomes. However, the drawbacks are the subjectivity of the individuals interpreting and scoring data.[6] Additionally, without demonstrating that two independent judges can be reliably trained to rate a particular behavior, achieving objective measurement of behavioral phenomena is diminished.[7]

A different faculty member is assigned to the design course for each freshman class at MSOE This is a consequence of past program assessment and an attempt to address subjectivity in interpreting performance. That faculty member leads her/his group through the "four-year" design sequence. The intent was to provide consistent interpretation of the design requirements for the students. Although student outcomes remained constant, each faculty member has his or her own technical strengths and there is varying emphasis among the different aspects of design as he/she leads his/her design group through the process. An individual faculty member would use his/her own assessment tool (rubric). While this process is not necessarily bad, there is inconsistent assessment data available to the faculty at their semiannual faculty assessment retreats. It is because of these difficulties that the faculty decided to develop consistent rubrics.

Rubric Development

How can the difficulties associated with having numerous faculty members assessing whether or not a group of students has adequately achieved defined outcomes be addressed? One possibility is repeatedly and consistently applying rubrics agreed to by all faculty members. Scoring rubrics are one of many alternatives available for evaluating student work cited.[8,9] Another advantage to a scoring rubric is that is considered a direct measure.

Once you have decided rubrics should be developed, questions arise. How do you create a rubric? Should it be base strictly on expectations of the faculty or on the listed course objectives? How do you establish levels of performance and have everyone agree on what that performance should be? Should you share the expectations with the students? If you do, will the "study for the test" phenomena occur and will they not understand the concept? To address these questions, straw-man rubrics should be created and shared with those who are doing the assessment. Efforts must be made to ensure that everyone shares the same understanding of the levels of performance.

The MSOE faculty are working to develop such rubrics. The purpose is to assess performance at four different points in the four-year MSOE design program. The four rubrics will be applied to the junior design presentations, to the two design reviews, and to the final design presentation in the senior year. The rubric for the junior design presentations is expected to measure a students' ability to communicate, whether or not there are measurable requirements, the quality of the presentation, and whether or not there is appropriate background research; literature, patents, FDA, etc. The version of the rubric used at the fall 2004 junior design presentation is shown in figure 1.

Discussion

Evaluators who used the rubric for the fall 2004 junior design presentation included MSOE BE faculty, Industrial Advisory Committee members, and senior BE students. There was significant variation among all three rating groups in all categories. Although only one data point, it appears that the rubric must be refined. One approach may be to refine the rubric scales and train the evaluators on the interpretation of the scales prior to the presentations as suggested by Stemler.[7] The expected results would be less variation in a group's interpretation of the scales. The training would likely mitigate the differing evaluator expectation of performance.

A great deal has been published on the use of rubrics for assessing student performance. However, far less has been published on the use of those rubrics for continuous program improvement. Variations in the student population and inter-rater? reliability must be addressed when applying a rubric for continuous program improvement. Interrater reliability can easily lead to improper conclusions.[7] Interrater variability was clearly evident in the

BE-301 Project Feasibility Presentation Evaluation Rubric

BE Design Team ______________________ Date __________

Project Title ______________________

Presentation Content

0 – 2	3 – 4	5 – 7	8 – 10	Remarks:
Missing a significant amount of required information	Missing two to three required sections without appropriate reasons.	Missing a required section without an appropriate reason.	Presentation includes most of the following: • Block diagram. • Overall Project Goal • Market Analysis. • Performance Specifications. • Current Technologies • Project Issues including limitations and/or constraints • team project schedule	

Research/Background of Current Technologies

0 – 2	3 – 4	5 – 7	8 – 10	Remarks:
Only Common Knowledge	Some attempt at research	Moderate depth but compatible with topic	In depth research compatible with topic	
No patent search	Suspect sources – News or popular media.	Adequate interpretation	Patent Search	
Little or no research			Accurate interpretation	
Inaccurate or poor recognition of sources	Poor recognition of sources	Some inaccuracy but recognizes sources	Recognizes sources	

Project Design Performance Specifications.

0 – 2	3 – 4	5 – 7	8 – 10	Remarks:
No design specifications	General design specifications with limited depth	There are clearly defined specifications	There are clearly defined specifications	
Overview of an existing product	Mimics existing Applications	Most specifications are: • detailed • quantifiable • measurable	All specifications are: • detailed • quantifiable • measurable	
No BE application				
NOT at appropriate level				

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BE-301 Project Feasibility Presentation Evaluation Rubric

Presentation

0 – 2	3 – 4	5 – 7	8 – 10	Remarks:
Difficult to understand	Hard to follow - Low content	Understandable but verbose	Well presented – logical flow	
Very colloquial	Mostly conversational style	Formal with some conversational style	Formal Professional style	
Incomplete sentences and ideas	Poor slide layout	"Clumsy" grammar	College level Grammar	
Project poster of little value	Poor graphics	Graphics of questionable use	Graphics support text	
	Reasonable poster	Reasonable poster	Well designed Poster	

Professionalism

0 – 2	3 – 7	8 – 10	Remarks:
Very unprofessional image	Somewhat of an unprofessional image	Very Professional image	
Appears to be no teamwork	Worked well with the team members	Worked well with the team members	
		Clear effective communication	

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Figure 1: Rubric used for the junior design presentation intended to measure the degree to which design teams presented the expected content, project research, proposed product specifications, presentation quality, and team professionalism.

evaluation of the fall 2004 junior design presentation and it could have been the result of a number of sources including:

- Variability in perceived project difficulty.
- Varying expectation of student performance.
- Design instructor bias; different faculty will emphasize different material.
- Difference among internal (faculty) and outside (invited) evaluators.

Another variable may be the student population itself. MSOE is considered to be a relatively selective engineering school. The average ACT score of the engineering student is 27 and they were among the top 10 to 15 percent of their high school class. Yet from year to year the performance, interests and goals of these students varies. How can proper inference be drawn from data collected from populations that differ from year to year?

Conclusion

Although most faculty may believe, as did Justice Potter Stewart, they know the quality of an engineering design project when they see it, it is likely that their assessment of design projects varies from year to year. A well designed rubric may reduce faculty variation, normalize interrater differences, and reduce year to year variability. The MSOE biomedical engineering faculty are developing rubrics for its design curriculum that they believe will produce more consistent results than alternative methods and that rubrics can be used to improve its design courses.

George Washington said that government is like fire: a handy servant, but a dangerous master. The same can be said for assessment. As with the Chinese Proverb; the wise adapt themselves to circumstances, as water moulds itself to the pitcher. Although many of us have been dragged into the assessment process by accrediting agencies, it must be a servant for improvement not a process for its own sake or for the sake of accreditation. Eleanor Roosevelt once said "Learn from the mistakes of others, you can't live long enough to make them all yourself." Engineering faculty must learn from the mistakes of others, deal with the differences among evaluators, and share what is learned to improve our lot in assessment.

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