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Design of Rubrics for Student Outcomes in 2019-2020 ABET Criteria

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Abstract – ABET is the main accreditation body for engineering programs in the United States and they have recently introduced a new set of Student Outcomes. This set was reduced from 11 to 7 items by combining several outcomes into one and adding some new ones. In our electrical and computer engineering programs we decided to design a set of seven general rubrics, one for each ABET outcome. These rubrics could then be used unaltered if course content fits them, or they can be adjusted to fit a particular course. To use a common description for rubrics, we wanted to keep the Performance Criteria the same but can adjust the Performance Indicators to suit a particular course. Six rubrics are presented in detail. We also share some initial observation in practical implementation of these in course and program assessment. They have helped us identify a problem in our sophomore cornerstone class related to the quality of student designs. Similarly, in our senior capstone-related class we identified a problem with defining and understanding ethical dilemmas.

Keywords – rubrics, assessment, evaluation, accreditation.

I. INTRODUCTION

Curriculum design of engineering programs is an ongoing process that has yielded many different approaches, each with its own strengths and weaknesses. The process itself is driven by many different factors, such as accreditation, available resources, government policies, and faculty beliefs. There have also been many calls for reforming, or even revolutionizing, engineering education, as well as increasing the number of engineering graduates, see e.g. [1] and [2]. Once new programs are designed and implemented, they must be assessed and evaluated.

Program assessment and evaluation are largely driven by various accreditation bodies. In the US, ABET is the main accreditation body for engineering and engineering technology programs. Accreditation requirements and procedures have exerted great influence on the structure and content of engineering programs. In the late 1990-s and early 2000-s, ABET started what is known as EC2000 criteria along with outcomes-based assessment and evaluation.

Even though the original intent was to allow flexibility in designing program outcomes, many programs (including ours) decided to keep the structure and requirements that ABET listed. These were the so-called “a through k” student learning outcomes (SLO), as discussed in, e.g., [4]. These were to be tied to program educational objectives (PEO). Both SLOs and PEOs were supposed to be assessed and evaluated periodically. For

example, we evaluated SLOs every year and PEO-s every third year.

Over time, however, it became clear that it was very hard to do proper assessment and evaluation of PEO-s, due to the requirement that they be evaluated three to five years after students graduate. In our experience, this assessment and evaluation turned out to be a logistical nightmare and it rarely produced actionable feedback. On the other hand, ABET’s insistence on continuous improvement approach to curriculum design and assessment has led to positive results because it shifted the emphasis from topics coverage to actual student learning, as discussed in [5] and [6].

Implementing their own requirement of “continuous improvement” ABET embarked on revising EC2000 criteria resulting in the new criteria listed in [3]. There are eight criteria used in program accreditation by ABET (quotations in italics are from ABET website [3]):

1. Criterion Students is concerned with evaluation, monitoring transfers, and graduation requirements.
2. Program Educational Objectives are “*broad statements that describe what graduates are expected to attain within a few years after graduation.*” In the past, programs were expected to assess and evaluate this criterion by, e.g., contacting graduates 3-5 years after graduation. At present, however, programs only have to document it and review it periodically.
3. Student Outcomes describe “*what students are expected to know and be able to do by the time of graduation. These relate to the knowledge, skills, and behaviors that students acquire as they progress through the program.*” This is where the bulk of assessment and evaluation of student learning is addressed. The results are used as inputs to Continuous Improvement.
4. Continuous Improvement describes what processes should be in place to ensure that the results of assessment and evaluation are used to improve a given program.
5. Curriculum – ABET does not require specific courses for each engineering program but it does give some requirements regarding e.g. number of credits to be devoted to math and science courses. It is in here that ABET declares that “culminating

major engineering design experience” must be part of curriculum.

6. Faculty, Facilities and Institutional Support are the remaining requirements but do not directly deal with students and their learning.

Programs undergoing accreditation evaluation tend to be most carefully examined on criteria 3 and 4. These also cover areas that faculty are most directly involved in through collection of assessment data and its evaluation. Faculty involvement and buy-in is a critical component of successful preparation for accreditation.

In the sections below, we first introduce rubrics and follow that up with a discussion of how our faculty used rubrics in assessment and evaluation of ABET Criterion 3. Lastly, we provide some concluding remarks.

II. BRIEF INTRODUCTION TO RUBRICS

Many benefits are claimed for rubrics, such as clarifying course or program goals, improving feedback, communicating expectations, etc. When used in courses, rubrics can be helpful in scoring course assignments [7]. Our intent is to use them for assessment and evaluation of student outcomes at the program or departmental level. Given that outcomes are defined at the program level, the rubrics will be more general than what one may use in a course.

The easiest way to explain the construction of rubrics is given in Table 1. As an example, we use “Systematically develops, compares and ranks design alternatives to arrive at a final solution” as one criterion in evaluating how well students apply engineering design. How well they perform is described by a performance indicator and the level at which student is performing. In this example, student who is performing at the “Proficient” level would “develop several good alternatives” but a student at the “Beginning” level would “Consider only one design.” Criteria, therefore, describe our general expectations from student work, and indicators give specific ways that students can demonstrate how well they have mastered them.

Table 1. Outline of a generic rubric in a table format.

Criteria	Performance level 3 (e.g. Proficient)	Performance level 1 (e.g. Beginning)
Criterion A. (e.g., Identifies)	Performance indicator 1 at level 3	Performance indicator 1 at level 1
Criterion B. (e.g. Develops ...)	Performance indicator 2 at level 3	Performance indicator 2 at level 1

We standardized on four levels of performance: Exemplary (4), Proficient (3), Developing (2), and Beginning (1). There are many other ways that these can be segmented and labeled but this set seemed to explicitly capture how we approach evaluation of student performance. Note that the performance indicators in this work are given only for the Proficient and Beginning levels to save space. In general, we consider that graduating students should be at the Proficient level. Exemplary level would typically be attained by a smaller fraction of all graduating students. Transition from Beginning to Developing to Proficient can be used to gauge student development within a course or, more

likely, within curriculum. Therefore, it may be quite acceptable in introductory courses to have a lot of students at the Developing or even Beginning levels.

Finally, rubrics that will be presented below are fairly general because they are meant to be used for program assessment. The expectation, however, is that individual instructors will tailor them to suit a particular course where they are being used. The initial development was largely based on author’s experience with cornerstone and capstone courses where they can be readily applied.

III. ABET CRITERION 3. STUDENT OUTCOMES

Student outcomes are broken into seven individual criteria, as discussed below. For each we quote ABET description followed by a discussion of how each is addressed by a rubric. Where possible, we describe our initial experiences and future plans.

A. Problem solving and analysis (outcome 1)

On the surface, this outcome seems to be the easiest to explain to engineering faculty because they believe that most of what they teach directly addresses this outcome:

“an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics” [3]

We have identified the following criteria to help us assess it. Note that each criterion listed below has several performance indicators, but they are not given here.

- A. Identifies problems with a quantifiable solution that can be approached systematically.
- B. Selects appropriate methods for solving the problem.
- C. Formulates the problem according to chosen solution method and identifies key issues/variables
- D. Recognizes the need for multiple solutions
- E. Analyzes alternative solutions to an engineering problem
- F. Justifies a solution to an engineering problem

This criterion is perhaps the hardest to express in a general rubric format because it varies widely across courses. There are several issues with devising appropriate criteria as well as the use of the rubric:

1. Faculty are used to assigning problems that can be solved in a relatively short time, for example, during a test. Somewhat longer problems may be assigned as homework, but this brings up issues related to copying from other students and from resources on the internet.
2. This results in problems that are not complex enough to be directly applicable to this program criterion.
3. It is only rarely that students are asked to consider multiple solutions and select the most appropriate ones. Sometimes this is implicit in the problem

itself but in order to evaluate it this needs to be an explicit requirement.

4. Justifying a solution is not normally required so long as students reach correct solution. To assess this properly, this must be required in the problem statement.

What these issues indicate is not that this is impossible to do, but that it requires careful consideration and explicit planning for assessing this outcome. Different criteria can be assessed and evaluated in different problems, but they need to be taken together to evaluate the overall student performance.

In the first year of use we have found the rubric to be valuable in formulating proper assessment questions in individual courses. Once faculty are familiar with individual criteria then it becomes easier to identify possible topic areas and assignments that can be modified so that they provide good assessment data. However, this is still an ongoing process and one that requires constant communication with the faculty who are tasked with this assessment and evaluation.

B. Engineering design (outcome 2)

“Design” shows up in the titles of many engineering courses. However, design means many different things and is dependent on the context. Engineering design is process oriented with the goal of devising a system, component, or process. Typically, it will have a specific targeted need (goal) and it involves a decision-making process. More complete definition and details can be found in [3]. Given this definition, ABET identifies the following outcome:

“an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors”

Our initial rubric addressing this outcome is given in Table 2. Note that only a subset of performance indicators is given, which suffices to illustrate what is going on and what we are looking for in students’ work.

One of the curricular issues related to this outcome is over-reliance of programs on demonstrating student attainment of it through assessment and evaluation of capstone projects. While this is an obvious time and place to perform this evaluation, waiting until the senior year makes it impossible to track student development, identify causes of observed issues, and implementing improvements. This is why we have added a cornerstone course in the sophomore year [8] as a follow-on to three freshman courses with significant, but somewhat basic, project component [15]. This course covers similar grounds as our capstone course but in a simplified form [10].

We have applied this rubric in the evaluation of designs produced by student teams in the cornerstone course taught in Winter 2019 term. There were 57 students in 15 teams. One area of concern was students’ inattention to formalizing requirements and constraints in their designs. Anecdotally, students like to dig into

technical challenges but consider formal requirements an unnecessary burden. This has led to changes how we teach and what we require from student projects. One change will be related to requiring that students justify their solutions by describing the design process and which alternatives they have considered. So far, we are observing student performance to be somewhere between Developing and Proficient, which is appropriate for a sophomore-level course.

Table 2. Criteria and a sampling of Performance Indicators for outcome 2 - Engineering Design

Criteria	Proficient (3)	Beginning (1)
A. Identifies and follows a logical and orderly design procedure.	Needs minimal help in identifying the procedure, understanding steps and staying on track.	No discernable effort made to identify or follow a procedure. Haphazard approach taken.
B. Systematically develops, compares and ranks design alternatives to arrive at a final solution.	Several good alternatives developed	Only considers one design option.
	Systematically compares and ranks alternatives	No evidence of systematic comparison or ranking
C. Creates a final solution that satisfies all requirements and constraints identified in formulating the design problem.	Requirements and constraints are appropriate and well justified	Identification of requirements and constraints in formulating the problem is missing or inadequate.
D. Justifies design decisions using analyses based on appropriate engineering and/or scientific principles.	Applies principles correctly for major design decisions	No analysis of design decisions performed.
E. Considers, where appropriate, factors: public health; safety and welfare; global, cultural, social, environmental, and economic	Produces a specific list of constraints resulting from these factors	No listing of constraints provided
F. Supports the design process with appropriate engineering documentation and references.	All supporting documentation is created. Minor improvements in quality are possible	Significant pieces of supporting documentation are missing or of a poor quality

C. Communication (outcome 3)

Ability to communicate has been identified not only as a very important ability for engineering students, but also as one in which they are persistently underperforming [9]. The new ABET outcome

“an ability to communicate effectively with a range of audiences”

was expanded from the old version by the addition of “range of audiences.” Given that students are asked to demonstrate this ability in a variety of contexts and audiences, our rubric is fairly extensive so that we report only on the simplified version, as given below. The rubric focuses on two main areas: written reports and oral presentations.

- Written report rubric criteria include: Content, Organization, Vocabulary and Grammar, and Mechanics (formatting, spelling, proofreading)

- Presentation rubric criteria include: Organization, Visual Aids, Technical Content, Posture and Tone, Handling of Questions, and Effective Use of Time

This rubric can be applied in many project-based courses as they typically require written and/or oral communication. Overall, we have found that written communication is more challenging for students than presentation one. It is also clear from our experience and from research that writing cannot be handled in isolation [11]. Instead, it must be taught and practiced across curriculum. One frequent issue is that faculty find it difficult to evaluate writing and we hope that this rubric will help alleviate some of these concerns.

D. Ethics and professional responsibilities (outcome 4)

Three outcomes from the previous ABET list of outcomes are now combined into one:

“an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts”

Assessment of this outcome is difficult. For the time being, we have focused on the first portion dealing with ethics proper by defining appropriate criteria, as given in Table 3. The second part dealing with “informed judgment” is interspersed in performance indicators, such as “Understands personal, professional, and wider social consequences of violations of codes.” In the future, we will attempt to address it more directly.

At this time, we have one 2-credit class that directly addresses this outcome, but we do not require students to take classes in ethics from other departments within our University. However, given the complexity of this new outcome this will be something to consider in our future curriculum development. Our initial evaluations indicate that students can easily identify ethical dilemmas related to safety, but they have difficulties in formulating more ambiguous dilemmas and identifying stakeholders. These results will lead to placing more emphasis on these items during class discussions and in assignments.

E. Teamwork and project management (outcome 5)

Teamwork was listed in previous versions of ABET student outcomes but the current description is expanded to include what we interpret to be project management:

“an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives”

In our newly developed teamwork and project management rubric, we use three performance criteria: Project planning, Project implementation, and Team functioning, as given in Table 4. The same table lists a selection of performance indicators to illustrate the kinds of behaviors and artifacts that we use in the evaluation.

Table 3. Criteria and Performance Indicators for outcome 4 - Ethics.

Criteria	Proficient (3)	Beginning (1)
A. Recognition of ethical dilemma	Clearly identifying the type of ethical dilemma	Not recognizing a problem at all
	Focused, clear, and detailed framing of a dilemma, not irrelevant digressions	Unfocused, unclear, not coherent description of a dilemma
	Clearly identifies stakeholders (those affected by the dilemma)	Stakeholders not identified
B. Providing relevant information for the case at hand	Produces well crafted arguments based on new information; justifies assumptions and brings information from their own experiences	Copies arguments from sources but does not critically examine them. Ignores pertinent facts or uses misinformation.
	Identifies critical issues & components of the new knowledge	Gets lost in unimportant details
C. Analysis and fairness	Provides clear arguments	Arguments are not clear or coherent
	Considers multiple points of view in their analysis; global view with perspectives from e.g. employers, professions, and society	Takes only one point of view when analyzing a dilemma
D. Ethics in professions	Familiar with the value and importance of professional codes	Cannot identify even the basic components of professional codes
	Understands personal, professional, and wider social consequences of violations of codes	Unaware of consequences of violations of codes of ethics

Table 4. Criteria and Performance Indicators for outcome 5 - teamwork and project management.

Criteria	Proficient (3)	Beginning (3)
A. Project planning (documentation, timeline, decomposition, requirements, specifications)	Project proposal provides full graphical and textual documentation for timeline, functional decomposition, requirements, specifications	Superficial planning document
B. Project implementation (planning, tasks, deadlines)	Team meets regularly	Team meets irregularly
	Tasks are specific, detailed, have responsibilities assigned with deadlines, and define when a task is done (who, when, what)	Intermediate tasks are too broad, lack responsible person, deadline, and definition of “done”
	Activities follow a plan	Activities driven by external deadlines - most activity just prior to some event
C. Team functioning (structure, communication, spirit)	Member roles and responsibilities are clear and effectively executed	Member roles and responsibilities are not clear
	Team contract is well written and team members stick to it	Team does not produce a team contract

We have used this rubric in evaluating teamwork and project management in our cornerstone courses where we use Scrum-like project management [8]. This enables continuous monitoring and feedback to students, something that was missing from the more traditional ways of organizing project-based courses [16]. So far, teams are having more problems in criteria A. and B., especially when it comes to implementing their plans in a complex academic environment. We also use peer-evaluation software CATME [14] to evaluate teamwork and are in the process of correlating it with the results from our rubric.

F. Experimentation and data (outcome 6)

It is hard to imagine engineers not doing some form of experimentation and this criterion describes it:

“an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions”

The second part dealing with engineering judgment is newly added. While there are many courses with associated labs, note that this criterion requires a development of experiments, which is more complex problem than simply conducting an experiment. Similarly, students have to be placed in situations where they have to exercise judgment instead of following instructions. This rubric is currently undergoing testing and revisions.

G. Life-long learning (outcome 7)

This outcome used to require only “recognition of the need for life-long” learning, but the new outcome

“an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.”

clearly requires that students demonstrate that they can do this. In the past, some form of survey may have been sufficient, but we now have to consider different approaches. Our initial rubric for it is given in Table 5.

Table 5. Criteria and Performance Indicators for outcome 7 - life long learning.

Criteria	Proficient (3)	Beginning (1)
A. Acquire new information	Examines all the widely known sources, e.g. internet and library	It cannot be determined which sources are used
	uses only reliable sources	does not examine reliability of sources or uses unreliable ones
	information used is current or appropriate mix of old and current	there is no way to discern how current the used information is
B. Apply new knowledge	Produces well crafted arguments based on new information	Copies arguments from sources but does not critically examine them.
	Identifies critical issues & components of the new knowledge	Gets lost in unimportant details
C. Learning strategies	Determined from survey [13]	

In the development of this rubric we tried to capture the active part, i.e. students doing things that require acquisition of new knowledge, followed by appropriate use of such knowledge. This was inspired by work done in [12], which seeks to evaluate whether information presented on, e.g., a website, is credible and valid. Their CRAP Test looks at four major areas: currency, reliability, authority and purpose. We now require students apply CRAP test to any presentation that involves research, such as analyzing a recent engineering ethics case.

In addition, we are trying to determine if students are deploying appropriate learning strategies. We are currently in the process of collecting data by using a published survey [13] and by using our rubrics in Table 5. Depending on our findings, we may deploy interventions addressing students’ metacognition, i.e. improving their understanding of their own learning.

IV. CONCLUSIONS AND FUTURE WORK

Program outcomes assessment is a critical component of accreditation. Recent changes in ABET criteria prompted us to reconsider how we perform student outcomes assessment. One critical part of our new approach to assessment is the development of general rubrics for each ABET outcome. Each rubric has several performance criteria and each criterion has several performance indicators. Not all criteria will be used in every course, but they can be adjusted to specific course requirements.

Initial implementation was done during 2018-19 academic year and we are currently examining possible improvements to rubrics and how we use them. Even in this initial form rubrics have been useful in identifying some specific issues at course and program level, such as placing different emphasis during ethics instruction, and clarifying the role of requirements and constraints in the engineering design process.

Faculty need training in application of rubrics and this is an on-going process. We hope that utilization of rubrics across courses in our programs will result in better uniformity and reliability of our assessment. We also hope that other programs will find this approach useful and are looking forward to exchanging information on successes as well as difficulties in implementing it.

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