# Improving Instruction and Assessment via Bloom's Taxonomy and Descriptive Rubrics

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## Abstract

This paper describes ongoing modifications to the ABET assessment procedures in the Mechanical Engineering Department at a San José State University, which is a large, primarily-undergraduate institution. These changes were made with the goal of improving alignment between in-class assessment practices and ABET assessment requirements. The first major change involves reviewing and revising the Performance Indicators for all Student Learning Outcomes. Specifically, the PI's were rephrased for strong alignment with the revised Bloom's Taxonomy, with a focus on higher order learning. The second major change is the development of descriptive rubrics for several major assessment tools. Two rubrics will be examined as examples: one for peer assessment of team members' contributions in the program's capstone design project and the second for a position paper on contemporary issues related to thermodynamics. Initial results from the revised rubrics showed several benefits, including ease and accuracy of assessment. Additionally, the authors suggest best practices for ensuring assessment alignment with ABET objectives by working backward from PI's to write rubrics for assessment tools.


## Introduction

Since the introduction of ABET's EC2000 criteria (Lattuca, Terenzini, and Volkwein, 2006), engineering programs have taken a wide range of approaches to assessment of Student Outcomes (Criterion 3). The research literature is replete with studies that present good assessment practices. However, it can be challenging to find the time to study the relevant research, choose the best practices for one's own program, and integrate those practices effectively, particularly when there may be many sections of courses with many different instructors.

This work in effect is a case study of work done to improve assessment practices at a large, primarily-undergraduate state institution. Major assessment improvements in the last few years have included:

1. Reworking performance indicators to improve alignment with Bloom's Taxonomy.
2. Developing descriptive rubrics to improve assessment of student performance.
3. Reverse-engineering descriptive rubrics to improve alignment with ABET outcomes.

## Background

ABET requires that all programs document student achievement of Student Outcomes--skills that students should attain by graduation--given as follows (ABET, 2016):

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) 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
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

It should be noted that significant changes to these outcomes have been approved by the ABET Engineering Area Delegation, to be implemented in the 2019-20 review cycle. For simplicity, this paper will refer to Student Outcomes (a)-(k) prior to the proposed changes, as they were in place when the work described in this paper occurred.

For each Student Outcome (SO's), ABET requires that individual programs devise multiple Performance Indicators (PI's), which are specific descriptions of concrete, measurable skills and knowledge that students should possess. PI's may vary widely even between similar programs, but it is agreed that they should be meaningful to the students, reliable and valid for assessment, and describe observable, measurable behaviors (Cabrera, Colbeck, and Terenzini, 2001). ABET recommends (ABET, 2015) that performance indicators utilize the revised Bloom's Taxonomy of the cognitive domain (Starr, Manaris, and Stalvey, 2008; Krathwohl, 2002) to describe expected performance. The revised taxonomy is divided into six levels:

1. Remember
2. Understand
3. Apply
4. Analyze
5. Evaluate
6. Create

Levels 1-3 are considered low-level cognition, while levels 3-6 are considered high-level cognition. Ideally, there should be a mix of Bloom's levels accounted for in the PI's so that students are required to apply the material they learn in both low-level and high-level ways. Bloom's Taxonomy has been applied to a wide variety of assessment practices in engineering, including forming the framework for assessment of a new Optical Engineering program (Mead and Bennett, 2009), creating learning outcomes for an entrepreneurship course (Wheadon and Duval-Couetil, 2013), and assessing instructional modules for teaching various skills outlined in the SO's of an electrical engineering program (Pimmel, 2003). Hussain and Mak (Hussain, Addas, and Mak, 2016) recently proposed a unique framework for automating assessment of program SO's by classifying PI's in accordance with Bloom's taxonomy.

Descriptive rubrics, which include detailed descriptions of the varying performance levels of a criterion rather than assessing on a generic numbered scale, have gained attention and popularity. A recent review of studies on the use of descriptive rubrics found positive effects on student performance, as well as, in some cases, a positive relationship between descriptive rubrics and student motivation (Brookhart and Chen, 2015). In one such study, students who were given a detailed rubric or used the same rubric to grade a classmate's writing assignment performed better on a writing assignment than those who did not (Lipnevich et al., 2014). However, care must be taken in developing such rubrics, as demonstrated by the work of Al-Qudah and Romond (Al-Qudah and Romond, 2017), who utilized a descriptive rubric to evaluate student outcomes in a senior-level writing course. Although the rubric included descriptors of various performance levels on several ABET outcomes, a majority of students found it insufficiently detailed with respect to the structure and purpose of the assignment. On the other hand, well-designed descriptive rubrics have been shown to have additional benefits, including improving consistency of assessment among multiple instructors [14].

A number of engineering programs have applied descriptive rubrics to assessing a wide range of ABET outcomes, including professional skills [15], ethics [16], writing skills [13], and design competency [17], [18]. From a practical perspective, descriptive rubrics are appealing because they can be tuned to target specific skills and describe precisely the expected outcome, such as in the work of Coso and Pritchett [19], who developed a rubric to specifically encourage and assess student consideration of stakeholders in design decisions.

**Review Performance Indicators for Improved Alignment with Bloom's Taxonomy**

The previous Performance Indicators for the program in question, which may be found in the Appendix, were developed well over a decade ago and were relatively untouched since then. The approximate alignment of the previous PI's with Bloom's taxonomy of cognition is found in Table 1. The PI's increased the specificity and level of detail in ABET assessment, but they had several shortcomings. Some PI's were difficult to quantify and assess, such as in the case of outcome (i) PI 1: "Are willing and able to learn new material on their own." In other cases, the PI's were aligned along subject areas or topics rather than cognitive levels, such as in the case of outcome (a) PI 1: "Use math (calculus, differential equations, linear algebra) to solve ME problems." Some SO's also lacked assessment of high-level cognition, as in (g)-(k)

Table 1: Alignment of Performance Indicators with Bloom's Taxonomy before changes.

| | Student Outcomes and Performance Indicators | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bloom's | a | | | b | | | c | | | d | | | e | | | | | f | | | g | | h | | | | i | | | | j | | | k | | | |
| Taxonomy | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 1 | 2 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 1 | 2 | 3 | 4 |
| Remember | | | | | | | ■ | | | | | | ■ | | | | | ■ | | | | | | | ■ | ■ | | | | ■ | ■ | | | | | | |
| Understand | | | | | | | ■ | | | | | | ■ | ■ | | | | | ■ | | | | | | | | | | | | ■ | ■ | | | | | |
| Apply | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ | ■ | ■ | ■ | | | | | | | | ■ | ■ | ■ | ■ | ■ | | | ■ | ■ | ■ | | | | ■ | ■ | ■ | ■ | ■ |
| Analyze | | | | | | | | | ■ | | | | | | | ■ | | | | | | | | | | | | | | | | | | | | | |
| Evaluate | | | | | | | | ■ | | | | | | | | | ■ | | | | | | | | | | | | | | | | | | | | |
| Create | | | | | | | | ■ | | | | | | | ■ | | | | | | | | | | | | | | | | | | | | | | |

During the summer of 2017, a faculty member reviewed the existing assessment practices and revised the PI's to improve measurability and alignment with Bloom's Taxonomy. The full, revised PI's may be found in the Appendix, and the updated alignment with Bloom's Taxonomy is found in Table 2. For example, the PI's for outcome (a) were revised to shift the alignment from subject areas to cognitive levels. Additionally, details on the specific ways in which students were expected to use math and science in problem-solving were added, as shown in Table 3. These details provide direction for instruction and assessment practices, and they are more concrete and measurable than the earlier PI's. Similarly, the PI's for SO (h) were altered to improve measurability, as shown in Table 4.

Table 2: Alignment of Performance Indicators with Bloom's Taxonomy after changes.

| | Student Outcomes and Performance Indicators | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bloom's Taxonomy | a | | | b | | | c | | | d | | | e | | | | | f | | | g | | | h | | | i | | | j | | | k | | | | |
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 4 | 5 |
| Remember | | | | | | | ■ | | | | | | ■ | | | | | ■ | | | ■ | ■ | ■ | ■ | | | | | | ■ | | | | | | | |
| Understand | | | | | | | ■ | | | | | | ■ | ■ | ■ | | | | ■ | | ■ | ■ | ■ | | ■ | | | | | ■ | ■ | | | | | | |
| Apply | ■ | | | | ■ | | | | | | ■ | ■ | | | ■ | ■ | | | | ■ | ■ | ■ | ■ | | | ■ | ■ | ■ | ■ | | ■ | | ■ | ■ | ■ | ■ | ■ |
| Analyze | | ■ | | | | ■ | | | | | | | | | | | ■ | | | | | | | | | | ■ | | | | | ■ | | | | | |
| Evaluate | | ■ | | | ■ | ■ | | ■ | | ■ | | | | | | | ■ | | | | | | | | | | ■ | | | | | ■ | | | | | |
| Create | | | ■ | ■ | | | | ■ | | ■ | | | | | | | | | | | | | | | | | ■ | | | | | ■ | | | | | |

Table 3: Performance Indicators for Outcome (a) before and after revision.

| **Student Learning Outcome** | **Performance Indicators** | |
|---|---|---|
| | **Before** | **After** |
| a. an ability to apply knowledge of mathematics, science and engineering. | 1. Use math (calculus, differential equations, linear algebra) to solve ME problems.<br>2. Use science (chemistry, physics concepts) to solve ME problems.<br>3. Use engineering principles (Newton's laws, fluid mechanics, thermodynamics, heat transfer etc) to solve ME problems. | 1. Apply differential and integral calculus, linear algebra, differential equations, and statistics to solving engineering problems.<br>2. Given a well-defined engineering problem, identify and explain the relevant science and engineering principles.<br>3. Given a well-defined engineering problem, apply science and engineering principles to make appropriate simplifying assumptions, select boundary conditions, apply suitable solution methods, and evaluate the solution for accuracy. |

Table 4: Performance Indicators for Outcome (h) before and after revision.

| **Student Learning Outcome** | **Performance Indicators** | |
|---|---|---|
| | **Before** | **After** |
| h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. | 1. Take into consideration the environmental impact when designing an engineering product.<br>2. Take into consideration the health/safety/societal impact when designing an engineering product.<br>3. Demonstrate understanding on the environmental/health /safety and economic tradeoffs (cost analysis) of engineering products, including those they design in course projects.<br>4. Identify global contemporary problems that involve ME. | 1. Identify the global, economic, environmental, and societal needs relevant to a given engineering problem.<br>2. Explain the impact of engineering decisions in a global, economic, environmental, and societal context.<br>3. Take global, economic, environmental, and societal context into account during the engineering design process. |

**Development of Descriptive Rubrics for Assessment Tools**

At San José State University, Thermodynamics is a four-credit, junior-level course in Mechanical Engineering. Students in this course are asked to write a one-page position memo on a contemporary governmental policy related to mechanical engineering; past topics have included the corporate average fuel economy (CAFE) standards, tax incentives for all-electric cars, and federal investment in renewable energy. Student scores on this memo are used to assess Student Outcome (h), the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.

In Fall 2016, the simple rubric shown in Fig. 1 was used to assess student performance on the position memo. Although the assignment description distributed to students was a bit more detailed, the assessment process was relatively holistic, with only three criteria represented on the rubric: professionalism, quality of sources, and quality of arguments. This leaves significant room for interpretation and variation. Although only one instructor was grading the students (N=39), the lack of detail on the rubric is concerning for the reasons mentioned previously, including potentially low student performance and inconsistency in assessment from student to student.

| Criterion | Points Awarded |
|---|---|
| Plagiarism present? If yes, automatic zero (**no rewrite allowed**) | 0 |
| References present? If no, automatic zero (rewrite allowed). | 0 |
| Professionalism (Spelling, grammar, format, word usage, phrasing) | 20 |
| Quality of sources | 20 |
| Quality of arguments (Clear, thorough, convincing, well-supported) | 60 |

Figure 1: Rubric used to evaluate student performance on position memo on contemporary thermodynamics issues in Fall 2015.

The following year, the same instructor developed a descriptive rubric, shown in Fig. 2. The goals of the instructor in developing this rubric were to improve ease and consistency of assessment, provide more detail to students, and improve student performance. Significantly more areas of performance were considered, and detailed descriptions were included for the various levels of each, including quantifying required performance when possible (e.g. allowable number of spelling errors, required number of citations, etc.). The assignment description distributed to students (N=40) was fundamentally the same, and one instructor again graded all the submissions.

Figure 3 shows a histogram of student performance on the position memo in Fall 2015 and Fall 2016, respectively. In both cases, a grade of 70% or above was required for achievement of outcome (h). After implementation of the detailed rubric, a significantly larger portion of

| | Outstanding (100%) | Good (90%) | Minimum (70%) | Unacceptable (50%) | Not Present (0%) |
|---|---|---|---|---|---|
| **Organization of Arguments (10 points)** | 3 arguments are organized effectively, and transitions are used between arguments. | 3 arguments are organized effectively, but transitions between the arguments are slightly abrupt. | 1 argument should be moved to improve effectiveness, or transitions between arguments are extremely abrupt. | The arguments are organized poorly and transitions are abrupt, but the memo's purpose is still clear. | The arguments and transitions are so poor that they impede understanding of the memo's purpose. |
| **Recognition of Opposition (10 points)** | The memo recognizes any major drawbacks or arguments against the thesis and refutes them in a clear, convincing way. | The memo recognizes the major drawbacks or arguments against the thesis and refutes them fairly well. | The memo recognizes the major drawbacks or arguments against the thesis, but does not refute them strongly. | The memo attempts to discuss arguments against the thesis but misses one major, obvious drawback. | The memo fails to mention any drawbacks or arguments against the thesis. |
| **Support for Arguments (20 points)** | All 3 arguments are strongly supported by relevant information from outside sources. | One argument is slightly weak and could be improved by adding information from one outside source. | Two arguments are slightly weak and could be improved by adding information from outside sources. | One argument is entirely unsupported by information from outside sources. | Two or more arguments are entirely unsupported by information from outside sources. |
| **Effectiveness of Arguments (20 points)** | The memo has a clear thesis, and all 3 arguments are distinct and in support of that thesis. | The memo has a clear thesis, but 1 argument is slightly indistinct, unclear, or weak. | The memo has a clear thesis, but 2 of the arguments overlap or are unclear or weak. | The memo's thesis or its arguments are unclear or poorly constructed, but the general purpose of the memo is still clear. | The memo's purpose and arguments are difficult to understand. |
| **Professionalism (10 points)** | Word choices, sentence structure, and tone are all appropriate for a professional, technical memo. | 1-2 small details (slang terms, casual phrasing, etc.) take away from the professionalism of the memo. | 3-4 small details (slang terms, casual phrasing, etc.) reduce the professionalism of the memo. | 5-6 small details (slang terms, casual phrasing, etc.) reduce the professionalism of the memo. | The memo is noticeably unprofessional in word choice, sentence structure, and tone throughout. |
| **Spelling and Grammar (10 points)** | There are no apparent spelling or grammar mistakes. | 1-4 minor spelling or grammar mistakes are made, none of which impede reading comprehension. | 5-9 minor spelling or grammar mistakes are made, none of which impede reading comprehension. | 10 or more minor spelling or grammar mistakes are made, and reading comprehension is slightly impeded. | Reading comprehension is significantly impeded by spelling and grammar mistakes throughout the paper. |
| **Sources (10 points)** | 5 sources of used, of which 1 is a peer-reviewed work, and the other 4 are reputable text or online sources. | 1 source (other than the peer-reviewed source) is missing or comes from a questionable source. | 2 sources (other than the peer-reviewed source) are missing or come from questionable sources. | None of the sources is peer-reviewed, but the others come from reputable sources. | 3 or more sources are missing or come from questionable sources. |
| **Citations (10 points)** | All work from other sources is credited using in-line citations. A citation style of choice is used correctly and consistently. | 1-2 errors were made in in-line citations or works cited, but all outside sources were still credited clearly. | 3-4 errors were made in in-line citations or works cited, but all outside sources were still credited clearly. | 5 or more errors were made in in-line citations or works cited, but all outside sources were still credited clearly. | Significant errors in citations prevented giving sufficient credit to outside sources, or citations were missing entirely. |

Figure 2: Rubric used to evaluate student performance on position memo on contemporary thermodynamics issue in Fall 2016.

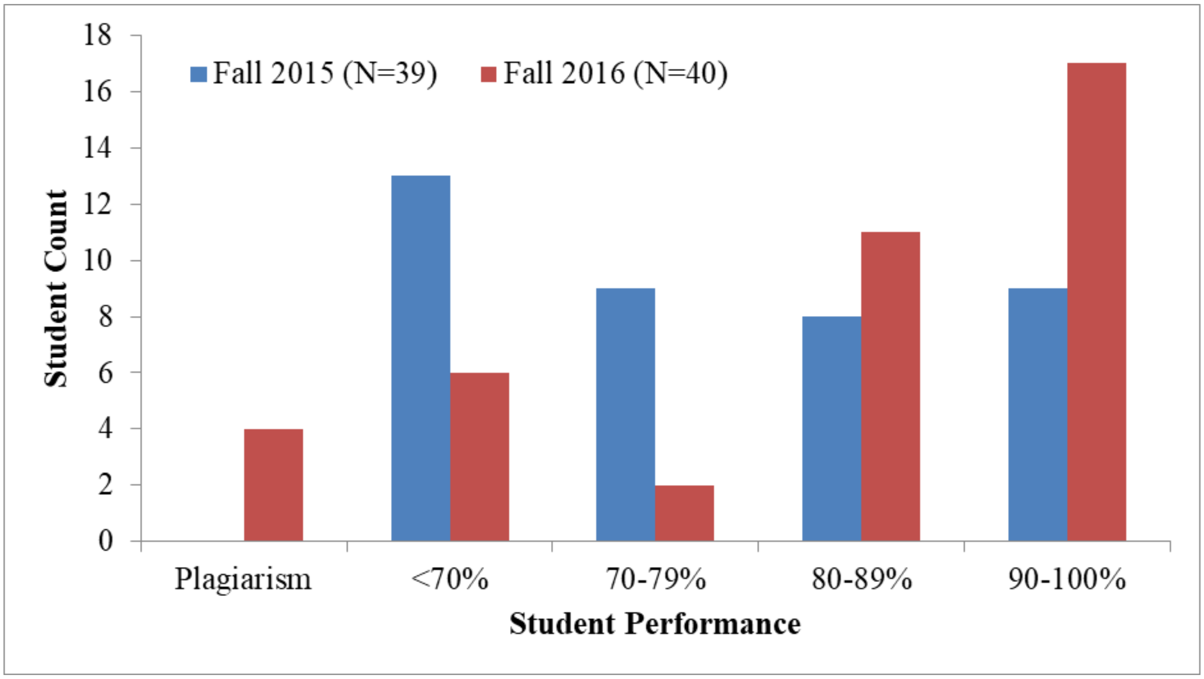


Figure 3: Student performance on position memo on contemporary thermodynamics issue in Fall 2015 (simple rubric) and Fall 2016 (detailed rubric).

students achieved A's and B's on the assignment, and fewer students failed to meet the performance threshold. However, plagiarism was detected in 4 students' papers, which amounts to 10% of the class. This may indicate that students require more stringent guidelines and thorough explanation of plagiarism and how to avoid it. Plagiarism aside, the remaining students performed significantly better with the descriptive rubric than with the simple one, and the instructor felt that grading was more consistent.

Although this is a significant improvement, students' grades on this assignment are still taken holistically to assess PI's 1 and 2 of outcome (h), although arguably only 50% of the points allotted on the rubric are related to students' understanding of the global impact of engineering practices, with the other 50% aligning better with outcome (g) an ability to communicate effectively. Thus, more improvement is needed to link elements of the rubric separately to both applicable SO's and PI's.

**Aligning Descriptive Engineering Rubrics with Performance Indicators**

An example of a rubric that is appropriately and specifically aligned with the appropriate PI's comes from the senior design sequence. In this sequence, students work in teams typically of four to six students over two semesters, with the fall devoted to design and the spring to construction, testing, and redesign. For the most part, common assessment rubrics are used across five sections of the class. Fifteen percent of the student grade is for individual student contributions, and one element that factors into that evaluation is a peer evaluation form. The department uses the peer evaluation form for assessment of ABET Outcome 3d Teamwork. The outcome with the old PI's—before recent revisions—is shown below.

<u>Outcome 3d -- an ability to function on multi-disciplinary teams</u>

ME graduates:

1. Participates fully in team, respects team members' opinions, resolves conflicts (if any)
2. Demonstrate team leadership by taking responsibility for various tasks, motivating others to reach project goals
3. Communicate ideas in ways that teammates can understand

The teamwork outcome was recently revised by ABET to be Outcome 5: "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." This change will require some minor revisions to the performance criteria and rubrics, but the general conclusions about the assessment improvement process remain the same.

The peer evaluation form used at the end of each semester through Fall 2015 is shown in Fig. 4. Using this form, students evaluated themselves and each teammate in ten areas. Questions 3 and 5 relate to PI 1, questions 1, 2, 7, and 8 to PI 2, and question 10 to PI 3. Assessment done in the 2013-14 academic year showed that for all Performance Indicators, the percentage of unacceptable scores (scores of 1 or 2) was below 2%.

Now, does this mean all students are truly stellar at teamwork? Probably not. One major problem with this form is the use of numbers to evaluate performance. Students tended to give all teammates the best score of "5" on all elements because it is unclear what standards should be used to assign numerical weights. Additionally, the usage of numbers can lead to inconsistency between evaluators -- what may be considered a "5" by one evaluator may be a "3" for another. As a result, this old form provided little meaningful feedback to instructors.

Using some elements of teamwork rubrics presented in ABET training [4], a new rubric was developed that used descriptive words rather than numbers for evaluation. The revised rubric is shown in Figure 5. Results from Spring 2016 are shown in Table 1, which also lists the relevant PI for each rubric element.

## ME 195 Individual Performance Evaluation

(adapted from http://pr.erau.edu/~whetten/classes/standards/team-eval.html, http://uhrm.uchicago.edu/forms/pdfs/emp_perf_eval.pdf, and http://www.engr.sjsu.edu/nikos/courses/engr10/teamcard.htm)

Part of your semester grade will be based on your individual performance as evaluated by you and your team members. Using your best, *objective* and *fair* professional analysis, complete the following evaluation form concerning your and your team members' performance over the semester. For the questions below, rate yourself and your team members using this scale:

1 = poor (unacceptable performance)
2 = fair (marginally acceptable performance)
3 = average (acceptable performance)
4 = good (often exceeds acceptable performance)
5 = excellent (truly superior performance)

Your Name: [redacted] (Y)
Member 2 – Name: [redacted] (2)
Member 3 – Name: [redacted] (3)
Member 4 – Name: [redacted] (4)
Member 5 – Name: [redacted] (5)

| | 5 | 4 | 3 | 2 | Y |
|---|---|---|---|---|---|
| 1. QUALITY of work on the project: done correctly, clearly, completely, attention to detail, recommends innovative solutions, seeks to continually improve work | 5 | 2 | 5 | 5 | 5 |
| 2. QUANTITY of work on the project: delivered on responsibilities, worked efficiently and in an organized manner | 4 | 1 | 5 | 5 | 5 |
| 3. Level of COMMITMENT given to the project/team: attended all meetings, came on time, was prepared and ready to work, was dependable and reliable. | 4 | 1 | 5 | 5 | 4 |
| 4. Demonstration of JOB KNOWLEDGE: understanding of project goals and tasks required to reach goals, applied appropriate knowledge and skills to accomplish tasks | 5 | 2 | 5 | 5 | 5 |
| 5. Ability to COOPERATE: accepts guidance willingly, works constructively with others on the team, 'team player' rather than 'lone ranger' | 5 | 4 | 5 | 5 | 5 |
| 6. Demonstration of JUDGMENT: identified and analyzed problems, developed effective solutions, managed time effectively, effectively prioritized work tasks | 5 | 2 | 5 | 5 | 5 |
| 7. ATTITUDE toward work on the project: positive, encourages others, seeks consensus | 5 | 3 | 5 | 5 | 5 |
| 8. INITIATIVE taken on the project: proactive, does not wait to be told what to do | 4 | 1 | 5 | 5 | 5 |
| 9. ADAPABILITY: ability to handle changes to job assignment, schedule, work environment | 5 | 2 | 5 | 5 | 5 |
| 10. COMMUNICATION skill: clear oral and written communication | 5 | 3 | 5 | 5 | 5 |
| **Totals=** | 47 | 21 | 50 | 50 | 49 |
| **Average (divide total by 10)=** | 4.7 | 2.1 | 5 | 5 | 4.9 |

Additional Comments (use the back if necessary):

Team member 5: Name: [redacted] Comments: Gave great guidance & tips with his industry experience. (5)

Team member 4: Name: [redacted] Comments: Showed little effort throughout semester, but took on responsibilities VERY LATE in semester. (4)

Team member 3 Name: [redacted] Comments: Well organized. Needed no supervision and always delivered quality work. (3)

Team member 2 Name: [redacted] Comments: ~~[illegible]~~ Knowledge of CAD programs was good assett to team. Very enthusiastic about project. (2)

Self – Comments: (Y)

Signature of evaluator [redacted] Date 12-10-2010

Figure 4: Example Peer Evaluation Rubric used through Fall 2015

| Evaluation Criteria | Beginning | Developing | Accomplished | Exemplary |
|---|---|---|---|---|
| Research and/or Analysis | Does no background research or engineering analysis | Some background research and/or analysis done, but not thorough | Acceptable research and/or analysis done | Exhaustive research and/or analysis done |
| Design decisions and innovation | Does not contribute to design decisions | Provides feedback on others' designs but makes few of their own | Regularly contributes to design decisions but may not be innovative | Makes major contributions to innovative design decisions |
| Communication | Unprofessional communication; designs incomprehensible | Either written or oral communication poor, but not both. | Design drawings and both written and oral communication clear. | Excellent written and oral communication; explains designs clearly |
| Punctuality | Does not complete team assignments | Completes most assignments late | Completes most assignments on time | Completes all assignments on time |
| Take Responsibility | Never volunteers for work and/or routinely blames others for failures | Tries to do little work ; neither assigns blame nor takes the lead on solving problems | Often volunteers for work; finds solutions to problem in his/her area of assignment | Works for a solution to problems, regardless who is responsible; contributes a fair share |
| Meeting participation | Skips many team meetings | Skips some team meetings and frequently late | Attends most team meetings and usually on time | Attends all team meetings and almost always on time |
| Attitude | Complains and/or argues with teammates frequently | Neutral | Generally has a good attitude about the project. Rarely argues or complains. | Gung ho. Compliments and motivates teammates. Helps resolve conflicts. |
| Listens to other teammates | Is always talking and only supports his/her own ideas | Usually does most of the talking and pushes ideas with little consideration of others | Listens to others' ideas but does not consider them as much as he/she should | Listens to and considers others' ideas thoroughly. |

Figure 5: New Peer Evaluation Rubric, used Spring 2016 onward

Table 5: Results of new Peer Evaluation Form, Spring 2016. "PI" indicates the relevant Performance Indicator.

| | PC | Beginning | Developing | Accomplished | Exemplary |
|---|---|---|---|---|---|
| **Research/Analysis** | 1 | | 10% | 50% | 40% |
| **Design Decisions and Innovation** | 2 | | 14% | 32% | 54% |
| **Communication** | 3 | | 14% | 44% | 42% |
| **Punctuality** | 2 | | 12% | 36% | 52% |
| **Take Responsibility** | 2 | | 6% | 38% | 56% |
| **Meeting Participation** | 1 | 2% | 4% | 38% | 54% |
| **Attitude** | 1,2 | | 12% | 48% | 40% |
| **Listens to other Teammates** | 1 | 2% | | 20% | 78% |

The results show a much greater spread of answers from students. While students still tend to grade their follow students very high, an average of 10% of students for each rubric element were given ratings of “Beginning” or “Developing”, compared to less than 2% using the previous rubric. The new rubrics provide instructors with more useful information to use when grading and to share with students when mentoring them for improved teamwork.

## Conclusions

Revising a program’s existing assessment practices may take a lot of time – developing performance indicators that accurately reflect the outcome, are measurable, and follow Bloom’s Taxonomy, along with creating grading rubrics that can be used across multiple sections of classes takes careful thought. However, this is a time investment that pays off with more informative assessment results and more uniform assessment across multiple evaluators. The assessment upgrades presented here are a work in progress at San José State University. New PI’s must be developed for the newly implemented Student Outcomes, and more rubrics that are tied directly to Performance Indicators must be developed. However, the improvements done to date are already providing better assessment results with which to improve our programs.

## References


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Appendix: Comparison of Performance Indicators before and after edits to improve alignment with Bloom's Taxonomy.

| Student Learning Outcome | Performance Indicators | | Changes |
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| | **Before** | **After** | |
| a. an ability to apply knowledge of mathematics, science and engineering. | 1. Use math (calculus, differential equations, linear algebra) to solve ME problems.<br>2. Use science (chemistry, physics concepts) to solve ME problems.<br>3. Use engineering principles (Newton's laws, fluid mechanics, thermodynamics, heat transfer etc) to solve ME problems. | 1. Apply differential and integral calculus, linear algebra, differential equation, and statistics to solving engineering problems.<br>2. Given a well-defined engineering problem, identify and explain the relevant science and engineering principles.<br>3. Given a well-defined engineering problem, apply science and engineering principles to make appropriate simplifying assumptions, select boundary conditions, apply suitable solution methods, and evaluate the solution for accuracy. | Switch from subject area orientation to Bloom's taxonomy orientation. |
| b. an ability to design and conduct experiments, as well as to analyze and interpret data. | 1. Based on an identified problem, design an experiment to acquire data to solve a problem.<br>2. Select appropriate equipment/instrumentation for an experiment to determine/measure the value of dependent variables from the given values of independent variables.<br>3. Calibrate the instruments from an experimental setup and follow procedures to collect data. | 1. Design an experiment to acquire data by determining the data to measure and formulating an experimental methodology.<br>2. Select appropriate measurement equipment, perform calibration, and acquire measurements.<br>3. Analyze and interpret the data, evaluate the validity of the results, and draw conclusions or make predictions. | Slight rewording for simplicity and Bloom's alignment. |

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| c. 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. | 1. Based on an identified need, define a problem statement in engineering terms.<br>2. Generate design concepts for a system, component or process and select the most suitable one based on the constraints in economics, environmental, ethical, health and safety, manufacturability, etc.<br>3. Develop design specifications (materials, geometry, operating parameters etc), perform analysis and design verification. | 1. Based on an identified need, define a problem statement in engineering terms.<br>2. Generate design concepts for a system, component or process and select the most suitable one based on the constraints in economics, environmental, ethical, health and safety, manufacturability, etc.<br>3. Develop design specifications (materials, geometry, operating parameters, etc.), and perform analysis and design verification. | No changes. |
| d. an ability to function on multi-disciplinary teams. | 1. Participates fully in team, respects team members' opinions, resolves conflicts (if any).<br>2. Demonstrate team leadership by taking responsibility for various tasks, motivating others to reach project goals.<br>3. Communicate ideas in ways that teammates can understand. | 1. Participate in project management, including assigning tasks to team members, developing a schedule, tracking progress, and adjusting the project schedule as needed to ensure completion.<br>2. Participates fully in team work, meets commitments and due dates, and contributes quality work to the project.<br>3. Treats all team members respectfully, communicates professionally and consistently, encourages and listens to ideas from all team members, and avoids and resolves conflicts when appropriate. | Rephrase for better alignment with Bloom’s taxonomy and ease of assessment. |
| e. an ability to identify, formulate and solve engineering problems. | 1. Define and articulate the problem in engineering terms.<br>2. Research and collect information pertaining to the problem.<br>3. Develop a plan to tackle the problem.<br>4. Draw on the pertinent subject knowledge/information and assess the accuracy of that information.<br>5. Monitor their problem solving process, reflect on its effectiveness, and modify the process as needed. | 1. Define and articulate a problem in engineering terms.<br>2. Research and collect information pertaining to the problem.<br>3. Select appropriate math, science, and engineering methods to solve the problem, and apply those methods to reach a solution.<br>4. Monitor the problem-solving process, reflect on its effectiveness, and modify the process as needed.<br>5. Evaluate the accuracy and significance of the solution. | Rephrased for better alignment with Bloom’s taxonomy. |

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| f. an understanding of professional and ethical responsibility. | 1. Demonstrate knowledge of a professional code of ethics.<br>2. Demonstrate an understanding of the impact of the profession or work products on society and the environment.<br>3. Demonstrate professional quality in project performance, punctuality, collegiality (teamwork), and service (volunteer) to the ME profession. | 1. Demonstrate knowledge of a professional code of ethics.<br>2. Describe and explain the ways in which the engineering profession and work products can impact society and the environment.<br>3. Describe the content and purpose of the Academic Integrity policy and follow the policy in all academic and professional activities. | Rephrased for better alignment with Bloom's taxonomy and ease of assessment. Added integrity policy. |
| g. an ability to communicate effectively. | 1. Produce well-organized reports, use clear and correct language and terminology when describing experiments, projects, or solutions to engineering problems.<br>2. Give well-organized presentations, use visuals to convey their message effectively and stay within their allotted time. | 1. Produce reports and presentations that use clear and correct language and terminology to describe context, methodology, results, and conclusions.<br>2. Produce reports and presentations of appropriate length (time) and technical breadth and depth for a given audience and setting.<br>3. Produce reports and presentations that use clear and effective visuals to supplement written or verbal descriptions. | Reframed from product-centered to quality-centered. |
| h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. | 1. Take into consideration the environmental impact when designing an engineering product.<br>2. Take into consideration the health/safety/societal impact when designing an engineering product.<br>3. Demonstrate understanding on the environmental/health /safety and economic tradeoffs (cost analysis) of engineering products, including those they design in course projects.<br>4. Identify global contemporary problems that involve ME. | 1. Identify the global, economic, environmental, and societal needs relevant to a given engineering problem.<br>2. Explain the impact of engineering decisions in a global, economic, environmental, and societal context.<br>3. Take global, economic, environmental, and societal context into account during the engineering design process. | Rephrased for better alignment with Bloom's taxonomy. |

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| i. a recognition of the need for, and an ability to engage in, life-long learning. | 1. Are willing and able to learn new material on their own.<br>2. Read articles / books outside of class materials.<br>3. Continue their education by attending student club meeting, campus workshops, seminars, conferences or plan to go graduate school upon graduation.<br>4. Can access information effectively and efficiently from a variety of sources. | 1. Demonstrate the ability to access and utilize information from external sources, including vetting sources for validity and synthesizing information from multiple sources.<br>2. Engage in long-term planning of academic and professional goals, including identifying the required education and licensure and identifying relevant professional societies.<br>3. Supplement in-class learning with student clubs, workshops, seminars, and conferences. | Rephrased for better alignment with Bloom's taxonomy and ease of assessment. |
| j. a knowledge of contemporary issues. | 1. Give examples of contemporary issues related to engineering and technology and articulate a problem statement or position statement for each.<br>2. Explain their relevancy to the present time.<br>3. Suggest reasonable/possible theories regarding the root causes of contemporary problems and identify possible solutions to contemporary problems. | 1. Give examples of contemporary issues related to engineering and technology and articulate a problem statement or position statement for each.<br>2. Explain the relevancy of contemporary issues to the engineering profession.<br>3. Explore the root causes of contemporary problems in order to identify possible engineering solutions to these problems. | Slight rephrasing for alignment with Bloom's taxonomy. |
| k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. | 1. Use modern technology for engineering system design, control, and analysis.<br>2. Use contemporary software to write technical reports and give oral presentations.<br>3. Use computer simulations to conduct simple parametric studies and design/process optimization.<br>4. Use modern equipment and instrumentation in their labs. | 1. Use modern software (word processing, presentation, and spreadsheet software) to produce quality reports and presentations on engineering topics.<br>2. Use solvers and simulators (ODE solvers, MatLab, Fluent, SolidWorks, etc.) to assist in engineering calculations, design, control, and analysis.<br>3. Use CAD software and fabrication/manufacturing tools (3D printers, CNC, etc.) for engineering design and prototyping.<br>4. Use modern equipment, instrumentation, and software (DAQ devices, sensors, Arduino, LabView) to make physical measurements. | Rewording to identify specific modern tools. |