New Rubrics for Assessment of Skills in Mechanical Design

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Introduction

Engineering educators realize that it is becoming increasingly important to assess student learning and improve educational processes. ASEE conferences and ABET workshops provide a great deal of general information on assessment and examples of approaches used at other colleges. However, it is up to individual programs to develop their own methods and procedures that work for their unique institutions. The goal of this project is to present a set of rubrics that were recently developed to assess student learning in a wide range of student outcomes in mechanical design. This assessment will be used as part of the continuous improvement process as required by ETAC/ABET.

Background

The Mechanical Engineering Technology (MET) program at SUNYIT has a traditional curriculum with typical required technical courses. More advanced courses with technical depth are required in the areas of mechanical design, thermal sciences, and computer-aided engineering graphics. Due to pre-requisites, students take the courses with technical depth during their junior and senior year, and they provide an opportunity of assessing student outcomes.

Rubrics have been used for several years to assess student performance in capstone projects. Although results lead to improvement in the capstone course, they were not directly related to student outcomes. The MET program needs a consistent method for direct assessment of specific student outcomes in a variety of courses with different instructors.

Rubric Design

The goal was to limit each rubric to one page with three to five concise performance indicators that captured the vital aspects of the student outcome. Proper selection of the verbs in the performance indicators was a very important aspect of defining the expectation of students.

Each performance indicator was evaluated with performance levels on a scale of one to four: 1 – Not acceptable, 2 – Below standards, 3 – Meets standards, 4- Exemplary.

This simplified scale helps to maintain consistency among instructors, and it forces a decision between acceptable (meets standards) and unacceptable (below standards). Each performance level contains a brief, thorough description of the expectations, clarifying the differences.
between the levels. The intent was to provide enough detail to distinguish between levels, while giving flexibility for use in evaluating student work in different projects and courses. The rubrics are designed to be used in upper-level courses that are well-aligned with the student outcomes.

**Results**

Rubrics were developed in the following three areas based on specific student outcomes:

1) Apply principles of solid mechanics in existing and new mechanical systems (Appendix A). This encompasses mechanical components undergoing combined loading conditions including tension, torsion, and bending. This outcome includes free body diagrams and analysis of stress, strain, and deformation. The rubric may be used in courses such as statics, strength of materials, stress analysis, and machine design.

2) Generate computer-aided engineering graphics using commercial packages (Appendix B). This includes wire-frame modeling with dimensions and tolerances, as well as solid modeling and applications in rapid prototyping and computer aided manufacturing. The rubric may be used in courses utilizing software such as AutoCAD, Pro/Engineer, and SolidWorks.

3) Design and modify components of mechanical systems: solid mechanics, fluid mechanics, and thermal sciences (Appendix C). This is a broad outcome that covers problem definition, background research, analysis, evaluation of alternatives, and communication of results. The rubric may be used in wide range of courses such as machine design, mechanisms, vibrations, heat transfer, thermodynamics, and capstone experience.

**Discussion**

The three rubrics developed during this investigation are prototypes to be used for a pilot study toward the end of the fall 2012 semester. Prior experience indicates that an effective way of refining the rubrics is to have different instructors use the rubrics to evaluate student performance in a variety of courses. Then, instructors can provide feedback and recommendations for improving the rubrics. It also helps to show the rubrics to students in advance, giving them a better understanding of expectations.

An advantage of rubrics is that they provide a fast and easy method to measure student performance directly related to student outcomes. However, effective use relies on genuine, honest evaluations by instructors. Some instructors, particularly temporary or tenure-track, may view the results as evaluations of teaching effectiveness, and so there may be a tendency for them to skew the scores upward. It is important to realize that it is acceptable for some scores to be low. In fact, one of the primary purposes of the rubrics is to identify areas for improvement.

Ideally, multiple evaluators should rate performance of students using each rubric. Although faculty teaching particular classes have the best understanding of their group of students, external evaluators would be less biased. Results from multiple evaluators could then be analyzed to
assess inter-rater reliability. Rubrics are not the only method for assessment. Although they are effective in terms of time and effort, multiple assessment methods must be used to validate the results and to reduce the bias of data from rubrics.

Conclusion

Although development of the rubrics took an initial investment of time, they are now useful tools for quickly and effectively assessing student learning. Each rubric may be completed by different instructors over a series of semesters to provide objective longitudinal results and direct measures of student learning. Summarizing the rubric scores for groups of students provides quantitative data to determine if outcomes are being achieved. The results may be used to determine strengths and weaknesses of the program, as well as to help identify areas for improvement.

Bibliography


Biography

DANIEL K. JONES, Ph.D., P.E., is Associate Professor of Mechanical Engineering Technology and Chair of Engineering Technology at SUNYIT in Utica, NY. He teaches courses in capstone experience, instrumentation, mechanical measurements, vibrations, machine design, and assistive technology for people with disabilities. He is working with faculty in several programs to develop assessment processes.
Appendix A. Apply principles of solid mechanics in existing and new mechanical systems

Course:  
Student Evaluated:  
Date:  
Evaluator:  
Project Evaluated:  

Performance Indicators for mechanical or structural components undergoing loading (tension, torsion, bending):

<table>
<thead>
<tr>
<th>Student demonstrated the ability to:</th>
<th>1 – Not acceptable</th>
<th>2 - Below standards</th>
<th>3 – Meets standards</th>
<th>4 - Exemplary</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Draw and label free-body diagrams</td>
<td>Omitted, vague, incorrect type of loading, supports not removed</td>
<td>Missing critical loads, dimensions, vectors or units; inadequate, sloppy</td>
<td>Includes most of the loads, dimensions, vectors, and units; neat and organized</td>
<td>Includes all loads, dimensions, vectors and units; part geometry is very clear, well-illustrated</td>
<td></td>
</tr>
<tr>
<td>b. Quantify stress and identify critical stress locations</td>
<td>Major errors in analysis; lack of magnitude or units; location or direction not specified</td>
<td>Multiple errors in analysis; incorrect magnitude, direction, units, or incorrect location</td>
<td>Valid computations, minor errors in analysis and results; location is approximate but not exact</td>
<td>Analysis is complete and thorough; results have the correct magnitude, direction, units, and location</td>
<td></td>
</tr>
<tr>
<td>c. Determine deformation (strain, elongation, angle of twist)</td>
<td>Major errors in analysis; lack of magnitude, direction, or units; no sketches</td>
<td>Multiple errors in analysis; incorrect magnitude, direction, or units; sloppy drawing;</td>
<td>Valid computations, minor errors in analysis and results; illustration shows most of the geometry</td>
<td>Analysis is complete and thorough; results have the correct magnitude, direction, and units; illustration is clear and fully labeled</td>
<td></td>
</tr>
<tr>
<td>d. Specify components for prescribed loading or deformation conditions</td>
<td>Major flaws in analysis; specifications are incomplete or incorrect</td>
<td>Inappropriate or flawed analysis; specifications do not fulfill all conditions</td>
<td>Minor errors in analysis and results; most of the geometric features or material properties are correct, including units</td>
<td>Analysis is complete and thorough; all of the geometric features or material properties are correct; multiple options</td>
<td></td>
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Appendix B. Generate computer-aided engineering graphics using commercial packages

Course: 
Date: 
Evaluator: 
Student Evaluated: 
Project Evaluated: 

**Performance Indicators**

<table>
<thead>
<tr>
<th>Student demonstrated the ability to:</th>
<th>1 – Not acceptable</th>
<th>2 - Below standards</th>
<th>3 – Meets standards</th>
<th>4 - Exemplary</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Create two-dimensional mechanical drawings</td>
<td>Lack of critical errors, missing features, numerous errors</td>
<td>Incomplete description of geometry, ambiguous shapes, broken lines or gaps</td>
<td>Create accurate depictions of parts with minor errors, recreate existing drawings</td>
<td>Professional quality, no errors, provides additional detail to existing drawings</td>
<td></td>
</tr>
<tr>
<td>b. Construct geometry for components and assemblies</td>
<td>Inadequate or incorrect representation of parts or assembly</td>
<td>Broken lines, gaps in geometry, unclear how parts fit into assembly</td>
<td>Parts and assemblies are clear, well documented with minor omissions</td>
<td>Very clear depiction of components and how they fit into assembly</td>
<td></td>
</tr>
<tr>
<td>c. Dimension and tolerance geometric features</td>
<td>Many missing linear or angular dimensions, units not specified, lack of tolerances</td>
<td>Incomplete specification, missing linear or angular dimensions, unclear units, incorrect or inappropriate tolerances</td>
<td>Most tolerances and fits are specified using standards, includes most of the details, minor omissions</td>
<td>Complete details for size and shape, all tolerances and fits are specified correctly</td>
<td></td>
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<tr>
<td>d. Create solid models and visualize spatial geometry</td>
<td>Model is incomplete or unclear, unable to depict spatial geometry</td>
<td>Unclear model boundaries, orthographic projections are incorrect or misaligned, not organized</td>
<td>Model is clear with minor details; accurate isometric, section, and auxiliary views; clear depiction</td>
<td>Complete detail, lifelike, high quality visualization, flawless multi-view projections, visibility of hidden features</td>
<td></td>
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Appendix C. Design and modify components of existing and new mechanical systems

<table>
<thead>
<tr>
<th>Performance Indicators (solid mechanics, fluid mechanics, thermal sciences)</th>
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<tbody>
<tr>
<td><strong>Student demonstrated the ability to:</strong></td>
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<tr>
<td>e. Define problem with sufficient scope and detail</td>
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<td>f. Gather adequate background information to utilize prior work</td>
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<tr>
<td>g. Evaluate alternatives with appropriate technical depth</td>
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<td>h. Specify crucial parameters and design details for effective system operation</td>
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