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Standards-Based Specifications Grading in Thermodynamics

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Introduction

Standards-based grading is being used more frequently in engineering courses [1], [2]. Clear, measurable standards or learning outcomes are required for this system. Instead of the course grade being determined based on scores of individual assignments and exams, the course grade is based on how many standards the student has mastered. Some benefits of standards-based grading include making the learning outcomes clear to the students, aligning each assignment with one or more learning outcomes, and taking the focus from the grade to the learning.

Specifications grading [3] is a relatively new system, with some similarities to contract grading [4]. In specifications grading, students are given specifications, or detailed requirements for successful completion, for each assignment or assessment. The work is then graded on a pass/fail basis. Assignments are grouped into bundles, and higher course grades require passing additional assignments or passing more challenging assignments. Students are given a small number of tokens, which can be redeemed to revise and resubmit an assignment that failed to meet the specifications.

Other higher education instructors have implemented specifications grading with some modifications. Some [5], [6] have found a four-level rubric [7] to be a better fit than pass/fail. In some implementations, students may have an unlimited number of revisions of some assessments [6]. While specifications grading is being used in a variety of disciplines [8], [9], there is little work on specifications grading used in engineering courses.

This paper will describe the implementation of standards-based specifications grading in a sophomore-level thermodynamics course in a mechanical engineering curriculum. Student performance on course assessments will be compared with work done by students in the same course taught the previous year using a traditional points-based grading system. Some student comments about the grading system and suggestions for implementation will be shared.

Description of Course Using Specifications Grading

In the fall semester 2016, standards-based specifications grading was implemented in a sophomore-level thermodynamics course. The course was designed using backward design [10]. The first step was writing the learning outcomes, or what students should be able to do by the end of the course. There were 33 of these outcomes, called “learning targets” [6]. Each learning target corresponded to one quiz question in the course. The other assignments and activities in the course were aligned with the learning outcomes.

The categories of assignments were quizzes, a group design project, and pre-class work of reading and responding to questions. The pre-class work was graded either “Pass” or “No Pass”. A “Pass” score was earned if the assignment was submitted before the start of class on the due date and if each question or problem had a response that reflected the student's good-faith effort to be correct [11].

The design project [12] was assigned to groups of 2 or 3 students. Group assignments were made using CATME [13], [14]. Each student group completed a report and gave a brief in-class presentation about their design. After receiving feedback, students had the opportunity to revise and resubmit the report, and revise the presentation.

There were a total of 33 quiz questions, each corresponding to a learning target. An example of a learning target is "I can apply an energy balance to a control volume at steady state, using appropriate assumptions and property data." A list of learning targets is given in the Appendix. Quizzes occurred in class, approximately every week. Students could retry any quiz question an unlimited number of times, until they were happy with the grade or until the end of the course. All quizzes were cumulative, containing new questions as well as new versions of previous questions. Students could therefore choose which questions to work on during the quiz time.

Quizzes and projects were graded using the four-level EMRN rubric [5], [6], based on the EMRF rubric [7]. Scores of "E" (excellent) and "M" (meets expectations) were passing. Scores of "R" (needs revision) and "N" (not assessable) were not passing.

The final course grade was assigned based on how many assignments earned a passing score and how many "E" scores were earned on quizzes and projects. Table 1 describes the requirements to earn a particular grade. All requirements for a grade had to be met in order to earn that grade. A "plus" grade was earned for a base grade if a student met all of the requirements for the base grade and one of the requirements for a higher grade. A "minus" grade was earned for a base grade if a student completed all requirements for the base grade except for pre-class work. A course grade of "F" was earned if the requirements for a "D-" were not met. A grade checklist was also provided to students to help them track their progress.

In the fall semester 2015, the course was taught using a traditional points-based grading system with exams, homework, quizzes, and a group design project. The weighting of each course component is given in Table 2.

Table 1: Course Grade Requirements

	D	C	B	A
Quizzes	Earn passing scores (E or M) on 15 core learning targets.	Earn passing scores (E or M) on all 18 core learning targets.	Earn passing scores (E or M) on all 18 core learning targets PLUS 7 additional learning targets.	Earn passing scores (E or M) on all 18 core learning targets PLUS 14 additional learning targets.
Quiz “E” Scores	None required.	None required.	Earn “E” scores on 18 learning targets.	Earn “E” scores on 25 learning targets.
Design Project	None required.	Earn passing score (E or M) on report. No presentation required.	Earn passing scores (E or M) on report AND presentation.	Earn passing scores (E or M) on report AND presentation. Earn “E” score on report OR presentation.
Pre-Class Work	Pass 7 pre-class assignments.	Pass 8 pre-class assignments.	Pass 10 pre-class assignments.	Pass 11 pre-class assignments.

Table 2: Grade Distribution in Traditional Grading System

Course Component	**Percent of Course Grade**
Exam 1	20%
Exam 2	20%
Design Project	20%
Homework and Quizzes	15%
Final Exam	25%

Student Performance

The 2015 course exams were reviewed to identify questions which corresponded to quiz questions in the 2016 course. These exams questions were then scored using the 4-level rubric used in the 2016 course. Student performance in the 2016 course (18 students) and the 2015 course (15 students) was compared.

Table 3 shows the percentage of students who earned a passing score in the 2015 class and the initial and final pass rates in the 2016 class. Four of the six compared learning targets were required to be passed in the 2016 class to earn a grade of “C” or better.

Table 3: Student Performance on Course Assessments

Learning Target	2015 Pass Rate	2016 Final Pass Rate	2016 Initial Pass Rate
I can evaluate expansion or compression work.	66.7%	94.4%	72.2%
I can analyze a closed system by applying energy balances and correctly applying sign conventions for work and heat transfer.*	46.7%	100%	11.1%
I can apply an energy balance to a control volume at steady state, using appropriate assumptions and property data.*	66.7%	100%	44.4%
I can evaluate the performance of power cycles and refrigeration and heat pump cycles using corollaries of the second law.*	93.3%	100%	61.1%
I can apply entropy balances in the analysis of closed systems and control volumes.*	53.3%	100%	11.1%
I can apply conservation of energy, the second law, and property data to determine Otto, Diesel, and dual cycle performance, including mean effective pressure, thermal efficiency, and the effects of varying compression ratio.	86.7%	11.1%	11.1%

*Passing this learning target was required for grade of “C” or better in the 2016 class.

The final pass rate for all compared learning targets except one were greater in the 2016 class than in the 2015 class. This topic (Otto, Diesel, and dual cycles) occurred late in the semester; therefore, there were fewer opportunities for reassessment. Additionally, many students were focused on passing the assessments that were required for a grade of “C” or better, and did not spend as much time on reassessments that were not required for a “C”.

While initial pass rates in the 2016 class were lower than the 2015 pass rate on 5 out of 6 of the assessments, an increase in pass rates was seen in all except one.

Student Comments

While there is some anecdotal evidence of positive student thoughts about this grading system, the students were not surveyed specifically about it. General student feedback was collected in two forms: the university end-of-semester course evaluation and a midterm feedback questionnaire. Both were anonymous. While the course evaluation was administered in both courses, midterm feedback was only collected in the 2016 course.

Only 3 of the 18 students completed the midterm feedback questionnaire. One student provided the following comment about the grading system and quizzes: “The major strength in this course that has helped me is being able to retry quiz questions I get wrong. I feel like I understand the material better when I see what I got wrong and have the ability study and try again.”

Sixteen out of the 18 students completed the course evaluation at the end of the semester. Some student evaluation comments were positive about the grading system. One student “liked how the coursework was tested and graded” and another noted that it “gives students plenty of opportunities to improve grade”.

Some negative student comments had to do with the number of questions and the time available for quizzes. One student noted the following: “Falling behind on quizzes was hard to get caught up.” Another student had similar concerns: “The quizzes were hard to catch up on. Once a couple of questions were missed on the quizzes, it seemed there wasn't enough time to redo the questions along with doing the new questions.”

One student comment expressed frustration over having to pass assessments from early in the course, perhaps instead of having a weighted average grade to make up for early work: “The grading scale that she is currently using could use some revising. One potentially has to go back to material from the beginning of the semester at the end of the semester to be able to pass the course.” One could argue that having to demonstrate mastery of all course material is a benefit of this grading system. In fact, one student said “I believe the grading method in the class encourages the student to build upon past knowledge and gives the student an opportunity to truly understand the material.”

Suggestions for Implementation

In the first version of this implementation, there were 33 learning targets. In a 15-week course, this is more than 2 learning targets per week, which became difficult to get through, especially later in the course. It is recommended to focus on only one learning target most weeks.

Initially, students could only do reassessments during the weekly quiz time during class. It was apparent during the last few weeks of the semester that some students would need more time and more chances for reassessment. During the last two weeks of the course, students could schedule an appointment with the instructor outside of class time to attempt reassessments of questions on which they had a score of “R”. It is recommended to provide some opportunity for reassessment outside of class time.

Students could attempt any learning target they wished, meaning toward the end of the semester, students were offered 20 or more questions and could choose which to work on. It became apparent that some students were not preparing for specific questions, but rather waiting until they got the quiz paper and looking through to see which they could do. This system also resulted in some students trying to earn a score of “E” on questions they had already passed, but not working on new questions. It is recommended to provide reassessments at the request of student instead of offering all questions.

Conclusions

Students were able to perform better on course assessments due to having opportunities for reassessment. The course preparation required more work before the start of the course. The time saved in not having to assign points was used to provide more feedback. Students had positive comments about the grading system, as well as constructive feedback to guide future implementations of the grading system. There is additional research to be done into student perceptions of standards-based specifications grading in this type of course.

Appendix: List of Learning Targets

1A. I can distinguish between a closed system and a control volume (open system).
1B. I can explain the following concepts in my own words: property, state, and process.
1C. I can explain the concept of equilibrium in my own words.
1D. I can explain the concept of temperature in my own words.
1E. I can use SI and English units for mass, length, time, force and temperature.
1F. I can solve simple pressure measurement problems involving manometers and barometers.
2A. I can evaluate kinetic and potential energy changes.
2B. I can evaluate expansion or compression work.
2C. I can analyze a closed system by applying energy balances and correctly applying sign conventions for work and heat transfer.
2D. I can conduct energy analyses of systems undergoing thermodynamic cycles, evaluating thermal efficiencies of power cycles and coefficients of performance of refrigeration and heat pump cycles.
3A. I can sketch T–υ, p–υ, and phase diagrams and locate states on these diagrams.
3B. I can retrieve property data such as specific volume and specific enthalpy from tables, using linear interpolation when necessary.
3C. I can use the generalized compressibility chart to relate p–υ–T data of gases.
3D. I can apply the ideal gas model for thermodynamic analysis.
3E. I can apply polytropic process relations.
4A. I can apply a mass balance to a control volume at steady state.
4B. I can apply an energy balance to a control volume at steady state, using appropriate assumptions and property data.
4C. I can apply mass and energy balances for control volumes not at steady state, using appropriate assumptions and property data.
5A. I can evaluate the performance of power cycles and refrigeration and heat pump cycles using corollaries of the second law.
5B. I can solve problems involving Carnot cycle applications of the second law.
6A. I can evaluate entropy and evaluate entropy change between two states.
6B. I can apply entropy balances in the analysis of closed systems and control volumes.
6C. I can use isentropic efficiencies for turbines, nozzles, compressors, and pumps for second law analysis.
7A. I can sketch schematic diagrams and accompanying T–s diagrams of Rankine, reheat, and regenerative vapor power cycles.
7B. I can apply conservation of mass and energy, the second law, and property data to determine power cycle performance, including thermal efficiency, net power output, and mass flow rates.
7C. I can discuss the effects on Rankine cycle performance of varying steam generator pressure, condenser pressure, and turbine inlet temperature.
8A. I can sketch p–υ and T–s diagrams of the Otto, Diesel, and dual cycles.

8B. I can apply conservation energy, the second law, and property data to determine Otto, Diesel, and dual cycle performance, including mean effective pressure, thermal efficiency, and the effects of varying compression ratio.
8C. I can sketch schematic diagrams and accompanying *T*–*s* diagrams of the Brayton cycle and modification involving regeneration, reheat, and compression with intercooling.
8D. I can apply conservation of mass and energy, the second law, and property data to determine gas turbine power cycle performance, including thermal efficiency, back work ratio, net power output, and the effects of varying compressor pressure ratio.
9A. I can sketch the *T*–*s* diagrams of vapor-compression refrigeration and heat pump cycles and of Brayton refrigeration cycles, correctly showing the relationship of the refrigerant temperature to the temperatures of the warm and cold regions.
9B. I can apply conservation energy, the second law, and property data to determine the performance of vapor-compression refrigeration and heat pump cycles and of Brayton refrigeration cycles, including evaluation of the power required, the coefficient of performance, and the capacity.
9C. I can apply conservation of mass and energy, the second law, and property data to determine the performance of vapor-compression cycle modifications, including cascade cycles and multistage compression with intercooling.

Eighteen (18) of the above were specified as core learning targets: 1A, 1B, 1C, 1D, 1E, 2C, 2D, 3A, 3B, 4A, 4B, 5A, 6A, 6B, 7A, 7B, 8A, and 9A. Proficiency must be demonstrated in these areas for a passing grade in the course.

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