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Work-in-Progress: Redesign of a Heat and Power Course

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Introduction

Traditional grading methods often include high-stakes assessments and may not account for a student's growth during the course. Grades can hinder student motivation and are not effective in providing constructive feedback [1]. Two recent review articles indicate an increased adoption of alternative grading practices in undergraduate courses [2], [3]. Key aspects of alternative grading systems include clear standards, helpful feedback, marks that indicate progress, and reassessments without penalty [4]. Some advantages of alternative grading methods include reduced student test anxiety [5], increased student self-efficacy [6], [7], improved students' motivation to learn [8], similar or higher learning outputs [9], higher grades in a subsequent course [10], and increased enjoyment of the course [11].

This paper describes the redesign of a heat and power course with an alternative grading scheme using elements of standards-based grading and specifications grading. The course redesign was intended to improve on a previous iteration of alternative grading. A secondary goal was to incorporate elements of self-determination theory, which posits that motivation is enhanced by supporting a student's basic psychological needs for autonomy, competence, and relatedness [12], [13]. This work describes the course activities and assessments and details of the grading scheme.

Project Approach

This paper focuses on an undergraduate heat and power course in a mechanical engineering technology curriculum, typically taken in the third year. The course is 3 credits, with lecture and laboratory components, and meets twice per week for 110 minutes per session. The work described here corresponds to the second time this instructor taught the course. The course was previously taught by other instructors using traditional grading methods. The course covers thermodynamics and heat transfer topics, and the course learning outcomes are as follows:

1. Determine properties of gases, steam, and refrigerants.
2. Analyze fixed mass and steady flow control volume systems and devices.
3. Apply fundamental concepts of the 2nd Law of Thermodynamics to heat-work energy conversion and thermal efficiency.
4. Apply basic conduction, convection, and radiation heat transfer concepts and equations to solve applied heat transfer problems.

From the course outcomes, a longer list of learning targets was developed to specify what students were expected to be able to do.

1. Convert between metric SI and English units commonly used in engineering.
2. Describe basic terminology of thermodynamics such as system, state, state postulate, equilibrium, process, and cycle.
3. (core) Sketch temperature-volume and pressure-volume diagrams of pure substances and locate states on these diagrams.
4. (core) Determine thermodynamic properties of pure substances.

5. Evaluate moving boundary work commonly encountered in reciprocating devices.
6. (core) Solve energy balance problems for closed systems that involve heat and work interactions for general pure substances, ideal gases, and incompressible substances.
7. Solve energy balance problems for common steady-flow devices such as nozzles, compressors, turbines, and throttling valves.
8. Describe terminology associated with cycles and cyclic devices, including thermal energy reservoirs, reversible and irreversible processes, heat engines, refrigerators, and heat pumps.
9. (core) Evaluate the performance of power cycles and refrigeration and heat pump cycles using corollaries of the second law of thermodynamics.
10. Solve steady conduction problems that involve multilayer rectangular, cylindrical, or spherical geometries.
11. Calculate heat transfer rates associated with external flow (over flat plates, cylinders, and spheres) and with internal flow.
12. Calculate radiation heat transfer between black surfaces.
13. Apply the log mean temperature difference method to determine the required size of a heat exchanger.
14. Preparation, participation, and practice (3P).

Learning targets 1-13 were assessed on quizzes taken during class. Each question/problem on the quiz was labeled with the corresponding learning target. Quizzes occurred about once per week, with each quiz covering one or two learning targets. Four times during the semester, “big quizzes” covered around 5 learning targets each. The final exam consisted of a required component and an optional component. All students were required to attempt the six “core” learning targets, even if they were already completed. Students also had one final attempt for all other learning targets.

Quiz and exam problems over learning targets 1-13 were marked “Successful” (S), “Revisable” (R), or “New attempt needed” (N) using the rubric in Table 1. This rubric was provided to the students at the beginning of the semester and discussed during class. The assessment method and marks are based on David Clark’s Introduction to Proofs syllabus and Sharona Krinsky’s Statistics syllabus [14] - [16]. The learning target quizzes with marks that indicate progress promote the psychological need for competence by providing transparency.

For a learning target to be counted as complete, a student needed to earn a mark of “Successful” on two separate quizzes. An initial quiz schedule was developed at the beginning of the semester and modified based on student need for new attempts. The quiz schedule used in the course is shown in Table 2. One final attempt for each learning target was available during the final exam. Due to time constraints at the end of the semester, only one “Successful” mark was required for Learning Targets 12 and 13 to be completed. The assessment model promotes student autonomy by providing reattempts without penalty and allowing for goal setting.

Table 1. Quiz/exam problem rubric.

Mark	Informal Meaning	Interpretation
S Successful	I know how to do this task. I can do problems independently. I can complete this task with good accuracy and few mistakes. I show all the steps and someone else can follow my work.	Student demonstrates understanding of the relevant concepts and solution methods. Solution of problems may include some minor errors, but they are irrelevant to the learning target. The solution is clear and complete. No additional study or review is needed.
R Revisable	I'm almost there. I can do most of the problem but need to fix or explain something. I will review this topic and explain how to correct the error.	Student demonstrates understanding of the relevant concepts and solution methods except for a minor issue that needs clarification or correction. Solution may be complete but some steps cannot be clearly followed. Student may revise for an S mark.
N New attempt needed	I do not quite understand how to do this task. I can complete the basics of this task in familiar situations only. I will review this topic and attempt a new problem on another quiz.	Student demonstrates partial understanding of the relevant concepts and solution methods. Solution contains a fundamental error, conceptual misunderstanding, or the solution is incomplete. Further study and a new attempt are needed.

Table 2. Schedule for which learning targets were assessed on each quiz. Quizzes 4, 7, 10, and 13 were designated as "big quizzes".

Quiz	LT 1	LT 2	LT 3	LT 4	LT 5	LT 6	LT 7	LT 8	LT 9	LT 10	LT 11	LT 12	LT 13
1	✓												
2	✓	✓											
3			✓										
4	✓	✓	✓	✓									
5				✓									
6					✓								
7		✓		✓	✓	✓	✓						
8						✓	✓						
9								✓					
10				✓	✓	✓	✓	✓	✓				
11									✓				
12										✓			
13				✓	✓	✓	✓	✓	✓	✓	✓		
14											✓		
15												✓	✓

Learning Target 14 was “Preparation, Participation, and Practice” (3P), which included three categories of smaller assignments. This was the only part of the grading scheme that involved accumulating points. “Preparation” was composed of pre-class and pre-lab assignments. These typically involved reading from the textbook or other resources, watching videos, and answering questions. The pre-class assignments included basic objectives that students were expected to achieve prior to class and advanced objectives in which they were expected to be proficient through additional practice. A student earned the points available for a Preparation assignment by attempting all questions with a good-faith effort to be correct and submitting the assignment prior to class. “Participation” was in-class activities, such as Peer Instruction [17] and informal problem-solving in groups. Points for these activities were typically recorded by the instructor after observing who was in class and engaged in the day’s activities. The in-class activities promoted relatedness by providing sufficient structure such that everyone participates. “Practice” was essentially homework problems, set up in a quiz format in the learning management system. Feedback was automatically provided after submission, and students could reattempt the problems while the assignment was open, typically for a few weeks. Points were earned for correct answers. Table 3 shows the different components of the 3P learning target and the total points available [15], [16]. A total of 230 points were required to complete this learning target.

Table 3. Points available for Preparation, Participation, and Practice assignments.

3P Activity	3P Points Available
Preparation	170
Participation	120
Practice	100
Total	390

Most weeks involved a lab activity based on an application of the course material. There were 10 of these assignments, which included experiments, simulations, practice with software, and case studies. Lab assignments, typically worksheets or memo reports, were marked either “Pass” or “No Pass”. What constituted work at the “Pass” level was specified for each assignment and made available to students when the work was assigned. After receiving feedback, students had the opportunity to revise and resubmit the assignment if a “No Pass” was earned. The lab assignments promoted competence by providing transparency through the specifications for each assignment.

After each “big quiz”, students were asked to submit a reflection assignment designed to promote metacognition. The questions below were assigned as the second reflection assignment, after the second big quiz (Quiz 7).

1. How did you prepare for Quiz 7? Did you make any changes in how you prepared for this quiz compared to Quiz 4? What study strategies or resources did you use (e.g., reviewed notes or textbook, completed Practice assignments in Brightspace, discussed course material with others)?
2. Think about your work on Quizzes 1-6. How did you use the feedback provided to prepare for Quiz 7? If you did not use the feedback, explain why.
3. Do you notice any patterns in your quiz performance? Are there any recurring types of mistakes (e.g., unit conversions, conceptual misunderstanding)? Are there any areas

where you have improved since Quiz 4 (e.g., conceptual understanding, clearly presenting your solutions)?
4. What changes will you make before the next few quizzes (e.g., study habits, time management, asking for help)? If you don't anticipate making any changes, explain why.

Reflections were marked either “Completed” or “Not Completed”. In order to earn a “Completed” score, students had to respond to each question/prompt with a good-faith effort to consider quiz performance, study habits and/or in-class participation and submit it before the assignment deadline (one week after the quiz was returned).

The final grade was determined by a two-step process, where learning targets and lab assignments counted for most of the grade, then adjustments were made based on the reflection assignments and the final exam [14], [16]. First, a grade was determined from Table 4 using the number of learning targets completed and lab assignments passed. The grade was the highest letter grade whose criteria were fully satisfied.

Table 4. Course grade requirements prior to adjustments.

Grade	Learning Targets Completed	Lab Assignments Passed
A	13	10
B	10	9
C	7	8
D	4	7

Next, adjustments were made for reflection assignments and the final exam. Using Figure 1, students moved one step right for completing all four reflection assignments, made no change for completing two or three reflection assignments, moved one step left for completing one reflection assignment, or moved two steps left for completing no reflection assignments. Finally, adjustments were made for the final exam. Students moved one step right for earning “S” marks on all four core learning targets on the final exam, made no change for earning “S” marks on two or three core targets, moved one step left for earning an “S” mark on one core target, or moved two steps left for earning “S” marks on no core targets on the final exam.

F	D-	D	D+	C-	C	C+	B-	B	B+	A-	A	A+

Figure 1. Letter grade “steps” for adjustments for reflection assignments and the final exam.

Discussion and Future Work

The course described here was the first time the instructor allowed revisions of quiz problems instead of only new attempts. The “R” mark was frequently used for complete solutions with small errors. Revisions were also used in cases where it appeared that the student understood how to solve the problem, but the solution was written in a disorganized way. Providing the opportunity for revision in these cases allowed for a lighter reattempt grading load and more discussions with students about their solutions and thought processes.

The quiz schedule provided structure for the frequency of reattempts. In other courses, this instructor gave quizzes over learning targets, but students requested reattempts when they were ready. In some cases, this led to an uneven workload and more work creating quiz reattempts at the end of the semester. Having the "big quizzes" spaced throughout the semester allowed for the instructor to have more control over the reassessment schedule and for an increased grading workload only during those weeks.

The first offering of the redesigned course has occurred, and student submissions to reflection assignments are to be collected. Future work includes analyzing the responses to the reflection assignments to study how students prepared for quizzes and used instructor feedback.

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