Graded Homework vs. Quizzes on Homework Material: Impacts on Student Performance in a Thermodynamics Course

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Abstract

Most engineering students need to solve problems in order to master the content of an engineering course. To facilitate this, it is common for instructors to assign homework problems that should help the students learn the course material. To encourage students to complete the work, many instructors allocate a portion of the course grade to homework. One difficulty with this approach is that the instructor does not know if the student is doing the homework, or if the student is simply copying another's solution (including from solution manuals) and submitting that work as his/her own. Another difficulty is that the grading of homework sets in a large class can become quite burdensome on the instructor depending on if help is available in the form of a grader. One approach that has been used to address these difficulties is to assign suggested homework problems and then give the students short quizzes on the homework material rather than grading the assigned problems. This approach has been adopted and tested in a second-semester course in Thermodynamics.

This course has been taught by the author nearly every semester for well over a decade, and the topical coverage in the course has remained fundamentally the same. Until the Fall 2015 semester, the homework component of the students was determined via grading the homework sets. Beginning in that semester, the assessment of the homework was done through short 10-minute quizzes on the assigned material on the date the homework was "due". The impacts that this change had on the performance of the students on the class mid-term and final examinations are considerable, as student grades on the tests were noticeably higher when using the homework quizzes. As the format of the course remained otherwise the same, comparisons between many semesters of students using both methods allows for a reasonable analysis of the impacts of the homework assessment mechanism. Because the exam grades are a good representation of student mastery of the course material, the use of homework quizzes is seen as beneficial to the students in this course.

In addition, thorough descriptions of the two methods of homework assessment and an explanation of the similarity of the course in different semesters over the years are included. Possible reasons why the quiz approach may improve student test performance are discussed.

Introduction

Instructors of engineering courses are faced with many challenges, and several of those challenges revolve around assigning and assessing homework. Most engineering students need to solve problems to fully understand the course material being presented to them in their engineering courses. To provide students with this problem-solving experience, some instructors have chosen to use the flipped-classroom approach, where students study the concepts and derivations traditionally taught in lecture outside of class and devote most class time to working problems in a group setting [1,2]. While this approach has worked for some instructors, many instructors choose to instead use the more traditional approach of lecturing on the material in

class, and assigning problems for the students to work on at home. Methods of assessing student homework in this traditional approach will be discussed in this paper.

Instructors use homework for many purposes. First and foremost, working homework problems provides the students with an opportunity to apply and strengthen what they have learned by solving problems related to the lecture material. Working problems also allows students to recognize what they may not understand, and make connections through the problems to help them learn the material. Some students will work with other students on homework problems, thereby building team-work skills as well as learning from others in the class. Some instructors encourage such collaborative learning by the students. Despite working problems being clearly beneficial to students, one of the challenges that instructors face is how to encourage the students to actually do the homework. To increase the amount of effort students put into the homework, many instructors allocate a portion of the course grade to the completion of the homework.

However, assigning a portion of the course grade to homework opens up new challenges. First, how does the instructor know that the student actually did the work rather than copying someone else's solution? Second, if the students do work in groups, how does one know that the student receiving a particular grade contributed anything useful to the group's solutions? Third, if one has a large class, how does one find sufficient time to grade the homework in a timely fashion? Of course, an instructor may use a grader or teaching assistant to help with grading if resources for such a person are available, but in such a case the instructor may not be getting good feedback on what the students may or may not understand in the course.

An approach that has been used to deal with these issues surrounding grading homework is to not grade the homework, but rather to give the students quizzes on the homework material. Such an approach can solve many of the problems associated with using graded homework as part of a course grade. But is such an approach effective in helping the students learn? To help answer this question, the author compared many years of course data in a second semester Thermodynamics course in the Mechanical Engineering Department at the University of Wisconsin-Milwaukee (UWM) Half of the semesters under consideration were operated using a graded-homework approach, and the other half of the semesters under consideration employed a method of suggesting homework problems and then giving short quizzes on the homework material. Below, after discussing the methods of assessing homework in more detail, the results of the students' performance on the course exams will be presented and observations from the results will be made.

Overview of the Homework Quiz Method

Homework has long been used as a method to improve student learning [3,4]. It is difficult to envision how most students in engineering courses would learn the material being taught without working problems. If a flipped-classroom technique is not used, then most students will have to be solving problems outside of class in order to master the material. If students are to work problems, and if they are to be encouraged to do by assigning a portion of the course grade to homework, there must be a method used to assess the student's performance. One approach is to grade either all or part of the submitted homework. A second approach is to not collect and grade the homework, but rather to give in-class quizzes on the homework material.

There have been various studies over the years to determine the effectiveness of homework and quizzes on student performance in a class [5-7], with mixed results. This is likely to be expected as the variety of student disciplines, student levels, and student abilities may make it difficult to reach a definitive conclusion. One result of note is from Bjerkaas and Wolberg [6] who found that a mixture of homework and quizzes was more effective at improving student performance than solely using homework or solely using quizzes. Because of the potential for different types of students (e.g., 1st-year vs. senior, engineering vs. physics) to have different impacts by how their homework performance is assessed, it is important to gather data on specific courses to determine which type of course might benefit from a particular assessment method.

The homework quiz technique used in this study appears to be very similar to that used by Jackson and Maughmer [8] in a junior class and a senior class in Aerospace Engineering. The specific method used in this current study is described below. Jackson and Maughmer found that the students averaged a 5-percent improvement in the junior-year required class, and a 10-percent improvement in the senior-year elective class. The course under consideration in this study, while a senior elective course, has many practical aspects that may make it have some characteristics of the junior required course in their study.

It should be noted that there is an increasing number of on-line homework options being offered. Some of these offer interesting potential benefits to the students and instructor. However, these are not the subject of this study, and should be thoroughly assessed as to their impact on student learning.

Description of the Course and Homework Assessment Methods

The course, MECHENG 402: *Thermo-Fluid Engineering*, is a second-semester course on Thermodynamics taken as an elective course by many students in the Mechanical Engineering Department at UWM. Table 1 contains a summary of the course topics currently in the course, and an indication of the topical coverage of the three exams. Material covered on one of the two mid-term exams is not repeated on the final exam. For example, there are 6 different Thermodynamic cycles covered in the course: the Rankine Cycle with modifications, the Brayton Cycle with modifications, the Otto Cycle, the Diesel Cycle, the Vapor-Compression Refrigeration Cycle, and the Reversed Brayton Refrigeration Cycle. The first exam contains problems on three of these cycles, and two of the remaining three cycles are the subject of problems on the final exam. Similarly, there are three psychrometric applications that are discussed in the course: cooling and dehumidifying, heating and humidifying, and mixing processes. The second exam has a problem on one of these applications, and there is a problem concerning one of the other two applications on the final exam. For combustion, there is one problem on the second exam on either a dry products analysis or a heat of combustion problem, and the other topic is tested during the final exam. The first and second exams both consist of 3 problems, and the final exam consists of 5 problems, four of which are similar in length to the problems in the first two exams, and the fifth is a shorter problem connected to the combustion material covered after the heat of combustion material (typically covered in the last week of the semester). Over the last 15 years, the course content (and instructor) has remained essentially the same, with the exception of the material that is covered at the very end of the course. That

Table 1: Current Topical Coverage in MECHENG 402.

General Topic	First Exam	Second Exam	Final Exam
Review of Thermodynamics			
Power and Refrigeration Cycles (6 cycles)	3 cycle problems		2 cycles not tested on first exam
Ideal Gas Mixtures		1 problem	
Psychrometrics (Fundamentals and 3 Applications)		1 application problem	1 application problem
Combustion (Dry Products Analysis and Heat of Combustion)		1 application problem	1 application problem
Adiabatic Flame Temperature/Fuel Cells/Chemical Equilibrium/Entropy Generation in Combustion			1 short problem

has changed between various topics over the years, but as one can see from the above description, the changed material amounts to a very small portion of the course grade (roughly 3% of the course grade). The consistency of instructor and the frequency with which he has taught the course has led to well-developed lectures that have provided students a similar lecture experience over the semesters considered in this paper.

Enrollment in the course has grown over the last several years. Figure 1 presents the number of students who completed the course each semester the course was offered since the Fall 2010 semester. During each semester, between 0 and 3 students did not take at least one of the mid-term exams or the final exam. These students are excluded from the analysis in this paper. (The total numbers of students excluded from the analysis are 7 for the quiz semesters and 8 for the graded homework semesters. For 10 of the 18 semesters, all of the students took all three exams.) Note that there was a general uptick in the enrollment in the course beginning in the Fall 2015 semester, which was the semester when the shift was made to using quizzes rather than graded homework to assess students' work on the homework. There were various reasons for this enrollment jump, including an increase in the number of Mechanical Engineering students with senior standing (and therefore being in a position to take technical elective courses), and an increase in the course enrollment capacity. One may also note a very low enrollment in the Fall 2016 semester. This is was a result of a course scheduling conflict where the course offering time overlapped with a required senior-level course; as a result, there were fewer students who had the scheduling flexibility to take this elective course.

Recognizing the importance of the students working homework problems, a portion of the course grade was determined by student performance on the homework. Prior to the Fall 2015 semester, student performance on homework was assessed via the grading of portions of the assigned homework. Also recognizing that the homework being submitted by students may not be solely their own work, the percentage of the final course grade attributed to the graded homework was only 5%. During the semester, 12 homework assignments were given, meaning that the homework assignments were nearly corresponding to the number of weeks in the semester. Each assignment had, typically, 4-6 problems from the textbook for the students to solve and submit. After the assignments were collected, the instructor would grade two of the

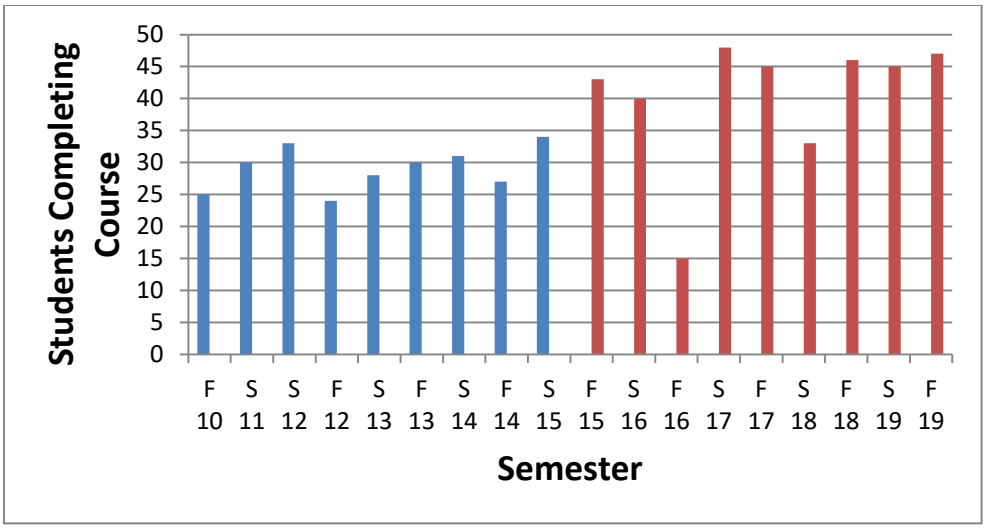

Figure 1: Number of students completing MECHENG 402 by semester. The blue represents semesters when graded homework was employed, while red represents semesters when quizzes were used to assess homework performance.

problems to sample the work of the students. Each problem was graded on a 2-point scale, with the grade given being determined by a combination of the correctness of the solution and the effort demonstrated by the student. Therefore, a student could still get 2 points for a solution that resulted in an incorrect answer but with the errors being a relatively minor part of the solution procedure. Also, after the homework was collected, solutions for the homework problems were posted by the instructor on the course website. This approach was reasonably successful in inducing students to submit homework solutions. Generally 75-80% of the possible assignments (12 assignments for each student multiplied by the number of students completing the course) were turned in by the class as a whole.

When the course enrollment capacity was increased in the Fall 2015 semester and the number of students in the course increased considerably, the instructor sought a different method for assessing student performance on homework. This led to the use of the graded quizzes on the homework material. In this method, 11 assignments were made of "suggested" problems for the students to work. On the day the assignment was "due", rather than turning in the homework for grading, students were given a 10-minute quiz covering the material in the assignment. As most of the suggested problems take longer than 10 minutes to complete, the quiz problems were usually a reduced version of the type of problem assigned where either some information that would have been needed to be found on a homework problem is given to the students, or the quiz problem just focuses on one aspect of a larger suggested homework problem. The quiz problems are different than the homework problems, but cover the same material. The quiz problems are designed in such a way that if the students did the suggested problems and understood what they were doing, they should have little difficulty in solving the quiz problems. The quizzes were open book and open notes, so students could refer to their homework solutions if they had done the work. These quiz problems were graded on a 5-point scale, with 5 points being given for a correct solution, 4 points for a nearly correct solution, 3 points for a solution with one significant

error, 2 points for a solution with minimal correct work, and 1 point for a solution with no substance. The portion of the final grade devoted to these homework quizzes remained at the 5% used for homework in the previous semesters. After the quizzes were taken, the instructor solved the quiz immediately in class so that students would have an idea of whether or not they solved the quiz correctly and what their mistakes may have been while the quiz was still fresh in their minds. Solutions for the suggested problems were posted on the course website shortly after the class in which the quiz was given. With the graded quiz method, typically 84-90% of the potential quizzes to be taken by a class are taken. This is noticeably better than the percentage of assignments that were submitted for grading. Furthermore, students needed to be present in class to take the quizzes, while under the graded homework format students had additional methods of turning in homework such as by giving it to a classmate to turn in or by giving it to the instructor outside of class.

Results and Discussion

The performance of the students as a whole in the nine offerings (Fall and Spring semesters of each year beginning in the Fall 2010 semester, but not including the Fall 2011 semester when the course was not offered) of the MECHENG 402 course prior to the change in homework assessment method has been compared to the performance of the students in the nine offerings (Fall and Spring semesters, beginning in the Fall 2015 semester) after the change was made. The data considered only includes grades from students who took both mid-term exams and the final exam. For each class, the averages of the class grades for each exam are combined into one score, which will then be divided by 3 to put the point total on a 100-point basis for ease of comparison. The results of this analysis are presented in Figure 2, with the data in blue being for semesters where graded homework was used, and the data in red being from semesters where homework quizzes were used. Note, there is no use of homework data in these numbers, as the numbers only use exam grades. Recall from Table 1 that the topical coverage for Exams 1 and 2 are identical, and the final exam topical coverage is the nearly the same, with only 10% of the final exam points connected to topics which may have changed from year-to-year. As some semesters may have more difficult topics tested on one of the mid-terms, and other semesters have this material tested on in the final exam, using an aggregate of the three test grades provides the best comparison between semesters, for this balances out any effects caused by when more difficult and easier material may have been tested.

For each of the sets of semesters using a common homework assessment mechanism, Figure 2 also presents a weighted average of the aggregated results. This average aggregate score is weighted by the number of students who completed all three tests in each semester. There are 262 students total considered in this weighted average for the graded homework method, and there are 362 students for the homework quiz method. The weighted average for the two data sets is presented as two dashed lines in Figure 2.

As shown in Figure 2, there are significantly higher grades in the semesters in which homework quizzes were employed. This can be seen directly in the difference between the two dashed lines. The weighted-average of the graded homework approach is 73.7, while the weighted-average for the homework quiz semesters is 79.7. This increase of 6 percentage points is noteworthy, and by itself suggests that the use of the homework quiz approach improves

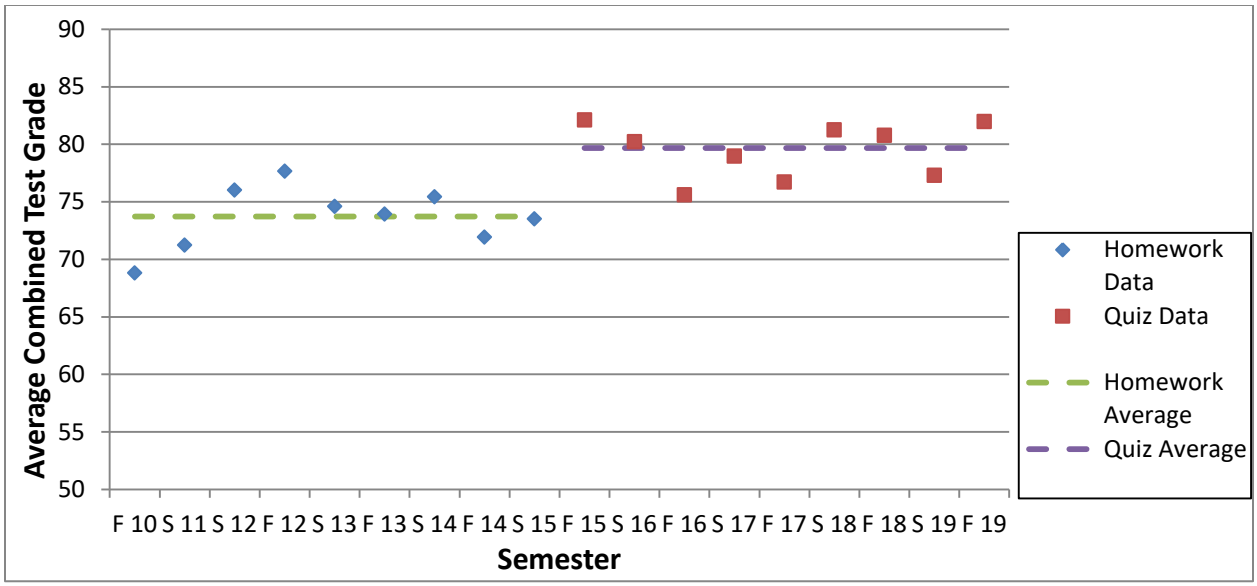

Figure 2: Semester-by-semester data for the average combined test score (scaled to 100 points) for the students in MECHENG 402. The blue diamonds represent individual semester data for semesters which employed graded homework, while the dashed green line represents the weighted average of these semesters. The red squares represents individual semester data for semesters which employed homework quizzes, with the purple dashed line representing the weighted average for these semesters.

student understanding of the course material, as represented by higher test grades. To further support the significance of this difference, an ANOVA analysis of the semester-aggregated data resulted in a p-value of 0.000 between the two sets of data.

It is also important to note in Figure 2 that a large increase in student performance occurred in the very first semester that the homework quiz approach was used (Fall 2015). Then, for each following semester, the average student scores were higher than the second highest of the graded homework approach, except for the Fall 2016 semester. The highest semester for the graded homework approach did exceed two other semesters for the homework quizzes, but it should be noted that the fewest number of students in the graded homework semesters was in the Fall 2012 semester. Similarly, the Fall 2016 semester had by far the fewest number of students in the course in the semesters under consideration. Semesters with lower enrollment can be more greatly impacted by outlying student performance. If there are a few students in a class who are particularly strong or weak students, the average grade in a class with lower enrollment can be more substantially impacted by the grades of those students. Therefore, a semester-by-semester comparison may not yield as clear results as one may get from an average over many semesters. Still, it should be clear from Figure 2 that when considering semesters separately, the average aggregate test performance is better in every homework quiz semester than most of the semesters with graded homework. Considering the results from the semester with the worst average test score performance using the homework quiz method (Fall 16), the average test score was still higher than in 7 of the 9 graded homework semesters. Six of the 9 homework quiz semesters saw an average higher grade than all of the graded homework semesters.

It may be of interest to compare how students, on average, did on the homework portion of their grade under the two assessment methods. The meaning of this comparison is not as clear as the exam comparison, as the nature of the assessment fundamentally changed. A comparison similar to that done in Figure 2 is done for the homework grades in Figure 3. The data in the graded homework semesters represents the average percentage of possible points earned by the students on the homework, with the dashed green line being the weighted-average over the nine semesters. The data from the homework quiz semesters is the average of the percentage of points earned by the students over the course of the 11 quizzes during the semester, with the purple dashed line being a weighted average. Considering that the grading of both the homework assignments and the homework quizzes is more subjective than the exam grading, on the surface there appears to be little difference between the percentages of points earned by the class through these two assessment methods. However, when one considers that the homework quizzes were being taken at a rate considerable higher than the rate at which homework assignments were being submitted for grading, it is reasonable to infer that students were being assessed slightly lower on their homework performance via the homework quiz approach (there were fewer grades of 0 to lower the average). Phrased differently, a larger percentage of quizzes were being taken by students under the homework quiz approach than the percentage of homework assignments being submitted under the graded homework method, but the total average score in terms of points earned was similar.

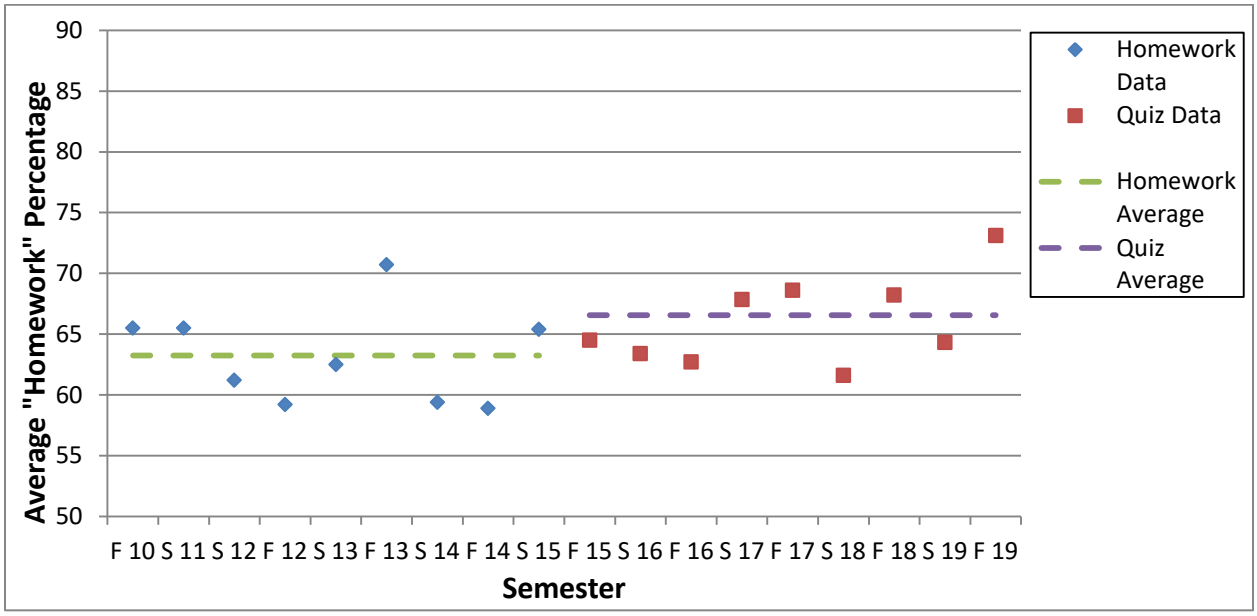

Figure 3: Semester-by-semester data for the average assessment percentage for the homework done by the students in MECHENG 402. The blue diamonds represent individual semester data for semesters which employed graded homework, while the green dashed line represents the weighted average of these semesters. The red squares represent individual semester data for semesters which employed homework quizzes, with the purple dashed line representing the weighted average for these semesters.

There are a few unknowns in this study with respect to homework completion. First, it is not known how many students before the assessment method change completed the homework after the homework was due and collected. Second, it is not known how many students in the homework quiz semesters ever do the suggested homework problems or how many assignments they complete. As different assessment methods are used, it may not be a safe assumption that the amount of homework completed is similar under the two assessment methods. One could reason that having to submit homework to be graded may induce greater completion of the homework, but one could also reason that knowing that they would have a quiz on the material might induce higher homework completion. So, without data, it is difficult to reason which method is likely to induce more homework completion.

With all this information considered, on the whole the homework quiz method results in better performance on the exams which in turn suggests that the students have greater mastery of the course material regardless of their homework assessment results. It is unknown whether that mastery carries on to their careers, but it still good that the students have better mastery of the course material while taking the course. But why is this the case? We propose three possible explanations, all of which may contribute to the improved performance. First, there is the simple observation that the use of the homework quiz method promotes better course attendance, at least on the days when quizzes are being given. As nearly half the classes in which new course material is covered has a quiz, improved attendance exposes a larger number of students to the lecture on this new material. Simply put, attending well-prepared lectures may aid the student learning of the material.

A second possible explanation is the use of immediate feedback on the students' mastery of the course material. As discussed, the quizzes are usually solved in class immediately following the quiz. What the students were thinking while attempting to solve the problem is fresh in their minds when the quiz is being solved by the instructor in class. If the students got the quiz correct, they have immediate positive reinforcement of their knowledge. If the students struggled with a portion of the quiz, they can remember what they were thinking while they are hearing and seeing the correct approach. If the students had little idea what to do on the quiz, the immediate feedback reinforces the idea that they still need to work through the material. Logically, this type of immediate feedback should be helpful to the students learning. While not a directly comparable activity, a consideration of the use of clickers in a classroom may be beneficial. It has been found that the immediate feedback provided by clickers allows students to determine their level of understanding of the material and to take appropriate measures to correct misunderstandings [9]. Similarly, the action of taking a quiz on the homework and then immediately reviewing the quiz allows the students to be made aware of shortcomings that they might have and feedback on how to correct those errors.

A third possible explanation builds off of the second explanation. If a student comes to class without having worked on the suggested problems, and then finds that they cannot just look at the book and figure out how to solve the problem in 10 minutes, the student receives immediate negative feedback regarding how well they know the material. This immediate feedback can act to encourage the student to work through the homework sooner, rather than later, to try to catch up with the rest of the class. Conversely, if a student does not turn in a homework assignment

that is to be graded, they have no reason to think that they would be able to get anything other than a "0" for the assignment. They knew this before the assignment was due, and still did not work on the assignment or ask questions on the material. So getting the "0" doesn't really change what they already knew about their work in the class. Because there are many examples of students who do poorly on the quizzes subsequently doing well on the exam (whereas there are fewer examples of students who do not do the homework that was to be graded doing well on the exams), it is possible that the presence of quizzes and the immediate feedback received by doing poorly on the quiz can act as a reminder to students to go back and work through the material on the homework well in advance of studying for the exam.

Ultimately, the exact reasons why students as a whole perform better on the exams with the homework being assessed through quizzes rather than graded homework is not as important as the understanding that the homework quiz method has produced positive results in this second-semester thermodynamics course. The reason why any particular student may benefit from the approach likely varies between students. Some may benefit primarily because they came to class more frequently. Others may benefit by receiving quick feedback that they don't really know the material very well and should spend more time trying to learn it before it gets to be the night before the exam. While these may be interesting psychological questions, from the perspective of an engineering instructor seeking ways to improve student mastery of the material, the results of the use of homework quizzes is most beneficial to consider in practice.

Some items to consider before choosing to implement the quiz approach are as follows. Is there sufficient time available in the lectures to devote to giving ~10-minute quizzes nearly every week? Is the maturity level of the students high enough that most students will still do recommended homework problems even if there is no grade directly attached to the homework assignment? Can homework-type problems be shortened appropriately to a short quiz question and still provide a meaningful assessment of the students' understanding of the material? If the answer to any of these questions is "no", then the in-class quiz method for assessing homework is probably not the appropriate method to use in that class.

Summary

A study was conducted over a period of 18 offerings of a second-semester Thermodynamics course, regarding the impact of how homework performance is assessed on how students perform on the course exams. In nine semesters, the homework was assessed by grading selected problems that were submitted by the students. In nine semesters, the homework was assessed not by collecting and grading homework, but through the use of homework quizzes that were connected to the homework material. The results show significantly-better performance on the exams by the students as a whole when the quiz method was used. While it was beyond the scope of this study to determine the exact reasons why the homework quiz method was beneficial, three possible explanations have been suggested. Furthermore, these positive results should encourage other engineering instructors to experiment with using homework quizzes as an alternative to grading homework. Even if the student-learning results are not as dramatic as in this study, in-class homework quizzes do greatly reduce the issue of knowing whose work is actually being assessed and used as part of a course grade as it is much more difficult for students to submit the work of others as their own on such a quiz.

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