

## The Role of Homework

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### Abstract

Many, if not all, engineering professors incorporate homework assignments into their courses in the belief that students will learn more. Students can practice the skills being learned and receive feedback on their efforts. These two principles are known to increase student learning. Data from two chemical engineering courses show that homework grades correlate with test scores and final grades even though homework is a small percentage of the course grade. Practice is more useful if it is frequent and if most students do it; thus frequent, relatively short homework assignments are probably preferable to infrequent but long assignments. Students should do something (homework, writing assignment, quiz, test, project) every week. Since immediate feedback while the students are working on the homework helps prevent excessive frustration, the availability of help will increase student learning if students use it appropriately. Prompt return of graded assignments is more effective than slow return, and students should be encouraged to use the feedback. This can be done by allowing them to turn selected reworked problems back in for an improved grade. Other methods of encouraging (or forcing) the students to practice such as group work during recitations are also effective in increasing student learning.

### I. Introduction

Assignments provide instructors with the opportunity to have students be active, involved, and doing things.<sup>1</sup> Numerous studies<sup>2</sup> have shown that students who are active and become involved in courses learn more. Unfortunately, without the encouragement and mild coercion of homework assignments, many engineering students will not study and become involved in a course. Since we want students to learn to solve problems, we need to assign homework.

In general, student learning increases if the course satisfies learning principles. The following learning principles are easily included as part of homework assignments: practice, feedback, successful students, and appropriate challenges. The relationship between doing homework and student learning is explored. As expected, data from two courses show that homework and test scores are positively correlated. Then, we will explore the details of assigning and grading homework. Homework should be directly related to the course objectives, include all levels of Bloom's taxonomy, have both relatively easy and relatively difficult problems, and be spread throughout the semester. Finally, other issues such as the availability of help and other ways to give students practice are considered.

## II. Learning Principles

A number of learning principles have been delineated<sup>2</sup> and several of these apply directly to homework assignments. The course should have clear learning objectives, and the homework assignments should correspond to these. In order to learn, students need *practice*. But practice per se doesn't necessarily make perfect—practicing incorrect methods is not helpful. As every athlete knows: Perfect practice makes perfect. Students need *feedback*. Since both *student success* and *appropriate challenges* are very motivating, it is important to consider the level of difficulty of the homework and to be sure that all levels of *Bloom's taxonomy* are included in the assignments.

Practice is clearly a major reason for requiring students to do homework. However, *homework is only effective if the students actually do it*. I have found that three types of encouragement are effective in motivating many students: when the homework grade counts towards the final course grade, when students are successful, and when they believe that doing the homework will help them do better on the tests.

These three motivating factors interact. If student efforts are successful, they will earn a higher homework grade. Both success and grades then motivate. If homework and tests correspond to the learning objectives, there will be a connection between the homework and the tests. Students who do better on the homework should do better on the tests. This indeed happens as shown in the next section. But if homework problems are all easy to ensure success, students may not be successful when faced with more difficult test problems. One solution to this dilemma is to start the assignment with relatively easy problems and work up to problems that are more difficult than any test problem. These difficult problems can appropriately challenge the better students in the class.

Essential to effective teaching is feedback, and two types are necessary for homework assignments. Students need a chance to study a correct solution, whether discussed in class, posted on the web or on a bulletin board, copied and passed out to students, or placed on reserve in the library. Correct solutions should be available for all problems that students are encouraged to try. Since students are most curious when they turn in the homework, the correct answers should be posted as soon as possible. But showing the students a correct solution is not sufficient. The second type of necessary feedback is to show students where they made errors. At least a subset of the problems students do must be graded. Many students believe that their solutions are correct until they see the red marks on their papers.

*Feedback is only useful if students use it*. Unfortunately, many students do not use feedback. How many times have you seen students pick up a returned test or homework assignment, glance at the grade, and then put it away in their backpack—or “circular file”—without studying the mistakes? Sometimes this occurs because the feedback is returned so late that there is no way the students can use it. The faster the students receive the feedback, the better. Many students will use the feedback if they receive credit for redoing problems they made mistakes on and can improve their grades.

### III. Correlations Between Homework and Learning.

The more homework assignments students attempt, the more they learn. For example, in a sophomore mass and energy balance course the average number of homework assignments turned in for students receiving each grade was<sup>3</sup>: A (7.44), B (7.55), C (6.82), D (4.33) and F (4.00). In this course, group work was encouraged on homework assignments. Since homework was only 5% of the course grade, just attempting homework assignments clearly affected test grades.

I also analyzed homework, test and grade interactions from the fall 2000 semester in the class ChE 306, "Design of Staged Separation Processes," at Purdue in which 120 students received grades. This required junior-level class, which is offered once per year, is essentially a lecture class with computer labs during the semester. The course grade was based on the following distribution:

13 quizzes (lowest dropped)	10%
Computer laboratory grade (7 labs)	15%
Homework (9 assignments)	15%
Tests (3 tests, 20% each)	60%

The first test score was increased by ten points to off-set a low average. This resulted in several students having a test score above 100. Students were assigned to groups for the computer laboratory and were encouraged to work in groups on the homework. This helped to harness the power of groups to help students learn. The downside was that some students undoubtedly copied the homework solutions without understanding them.

If doing homework assignments helps students learn the material, there should be a positive correlation between scores on the homework and test scores. The Excel scatter plot for total test points versus total homework points is shown in Figure 1. Because of the arbitrary increase in the first test score, two students are slightly above the maximum of 60 points. The line is the best linear fit. The  $R^2$  of 0.2919 is not exceptionally high, but does show the expected positive correlation. If we could separately plot the results for students who either worked on the homework independently or were major contributors in their groups, I expect we would see a much more significant correlation.

We would expect homework scores to correlate more closely with the total points (final grades) since homework points are a component of the total. This scatter plot (not shown) has  $R^2 = 0.5311$ . As expected this correlation is much higher.

### IV. Detailed Procedures

Since we want student success on some problems and student challenge on others, the assignment needs to have a range of difficulty. To avoid student complaints of unfairness, the difficulty of homework should bracket the difficulty of tests. Some of the early (easier) problems should instruct students to use a particular technique (e.g., "Use the Kremser equation.") to solve a problem. Otherwise, some students will never learn certain techniques. Since students need practice in sorting out what is

important, other problems should not spell out which techniques to use. Homework assignments are an appropriate place to include problems that require students to find or estimate data. Encourage students to use both literature sources and the web. Assignments also can include important problems that are too long to include on tests.

Be sure to cover all levels of Bloom's taxonomy<sup>2,4</sup>. As engineering professors we all regularly require application and analysis in homework, but we also need to be sure that students do synthesis and evaluation problems. It is easy to develop synthesis problems (e.g., "Brainstorm 50 ways to ...."), but grading them without stifling creativity can be difficult. Another synthesis assignment, which is easier to grade, is the "generic quiz."<sup>5</sup> In the sophomore mass and energy balance class the course project requires groups to prepare an original homework problem using the mass and energy balance principles they have learned. They are graded on correctness of the problem and solution, and on the originality of the problem. In our graduate level course on teaching engineering<sup>2</sup>, we have graduate students individually write a test for the course, complete with a solution and scoring guide. It is also fairly easy to write evaluation problems. For example, give the students five solutions to problems, four of which have errors. Be sure to include at least one solution that is correct. An alternative is to follow Mafi's<sup>6</sup> advice and have the students grade other students' homework. This not only provides experience at one form of evaluation, it also reduces the grading load.

How many assignments per term? The guiding principle here is to have students *do* something every week – HW, oral presentation, quiz, test, project, problem solving in recitation etc. Unfortunately, students often do not do reading assignments when that is the only assignment. Of course, it is reasonable to ask the students to do more than one item per week, particularly if one or more tasks are brief.

The appropriate length of an assignment depends on the number of assignments during the term and the other tasks due that week. It is useful to develop a rhythm during the semester. For example, one can start with a modestly difficult assignment, then a more difficult, long assignment to show students this is a serious course, and then an easier assignment either before or after a test. Then repeat the cycle. There does not appear to be any advantage to a slow start during the semester. Years ago I tried a slow, measured start and found that students weren't ready to start working regardless of the speed of the start. Now I give the students a reading assignment the first day and a homework assignment the first week.

One downside to increasing the number of assignments is that the TA or the professor can become overloaded, but this load can be reduced by realizing that you don't have to grade everything. Just be clear on what has and has not been graded. Assigning groups to work on homework can also reduce grading; however, if this is done there also needs to be individual student accountability.

How much should homework count in the final course grade? The more it counts, the more effort students will put into homework. But increasing the value of homework will encourage students to copy other students' solutions. My compromise is to make

homework five to fifteen percent of the course grade, and I show students the correlation between homework effort and final grades.

A related problem is how to treat assignments that are turned in late. I like to treat them in the same way that late work is treated in industry. It is accepted, but grudgingly. In other words, there is a price. How big a price depends upon how late they are, the reason, and whether the solution was posted before they turned in the assignment.

Old tests make excellent homework assignments since they do not have to be collected or graded for the students to try them. Of course, distributing old tests means new tests have to be written. Students appreciate receiving examples of old tests. Another advantage of handing out old tests is that it evens the playing field. Students with access to files lose their advantage. Although you do not need to collect and grade old tests, you do need to provide feedback on correct solutions. Post them and be prepared to answer questions in help sessions.

## V. Other Issues

The difference between student success and failure on homework assignments often depends upon the availability of help. First, try to get students to use their own resources such as the textbook, friends in the class and their study group. Unfortunately, these resources are not sufficient for some students who need regularly available help from teaching assistants or the professor. If you have TAs be sure they meet their regular office hours. Teaching assistants will be much better prepared for their office hours if they are required to attend lectures. Professors also need regular office hours when the students can count on their being available.

Students who commute or work and do not have easy access to office hours will appreciate and benefit from other forms of help. One method that I have found useful is e-mail with fairly rapid response. Telephone office hours are also useful particularly for distance education students. Development of a web page with a frequently asked question (FAQ) section is also helpful. The availability of help can eliminate excessive student frustration and increase learning.

Typographical errors have a way of creeping into even the most carefully proofread homework assignment. I use e-mail sent to the class alias to correct homework assignments or to add missing information. This is helpful in addition to mentioning the corrections in class.

Students will learn more and do better on the homework if they will do the reading assignments, but how can you get students to read? There are several possibilities:

1. Short quizzes at the beginning of the period. Even short multiple choice quizzes will encourage reading.
2. Homework that cannot be done based on lectures, but is fairly easy based on the reading.
3. "Extra credit" for proof that students have read the assignment.

4. Assignments that require students to summarize the reading, perhaps including the two most important equations.

Recitations are another way to get students to work on assignments. Since students already have normal lectures, lecturing in recitations is not particularly effective. Students love it, but watching the professor or TA solve problems has limited effectiveness. Students need to solve problems themselves. Cooperative groups are very effective for problem solving in recitations<sup>2</sup>. Groups can often solve problems that none of the students could do independently. They also provide emotional support for students and increase the time on task of extroverts. In addition, groups reduce the number of people that need help since the entire group can be helped simultaneously. A very modest grade (say 5% of the total course grade) based on attendance and effort during recitation ensures that the students who most need to come will attend.

With a little effort and planning, homework will engage the students in solving problems, which helps them learn the material. Thus, homework complements lectures and tests ensuring that the course satisfies learning principles.

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Figure 1. Test scores versus homework points

