Designing Homework Assignments: From Theory to Design

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Abstract

Implied by the university teaching contract, rather than explicitly detailed, is the expectation that faculty will make the very best possible effort to help the student "learn" the subject matter under instruction. One aspect of teaching relegated to the "have always done it that way" is homework. Some would call homework an "intuitively obvious" technique. However, just what constitutes homework and how it could be utilized is seldom usefully defined or sufficiently detailed to really help the new professor in his expected duties. A large number of studies have consistently shown that students benefit greatly from active learning programs such as those that require work outside of the classroom. Workshops, courses or programs that address appropriate application of homework seem to be rare

This paper addresses some of the reasons why homework is an appropriate technique to be included in any teaching portfolio. It defines the four basic types of homework, how the homework assignment should be processed, and what the instructor and the student can expect from well designed and executed homework assignments. Examples of course objectives and homework designed for freshman technology courses are presented. A scheme for recording and reviewing the homework design is also suggested.

Why homework is important

Virtually all active learning techniques have been shown to be a significant factor in improving student understanding of the material. Properly executed, these programs can shift the emphasis from instructor performance to student learning and change a passive student into an active learner. The additional student time-on-task is necessary to allow exploration of the various nuances of the topic. However, it is difficult to establish and maintain a comprehensive outside study program.

After examining several studies concerning the definition and application of the homework process, Cooper [1, 2] has very strongly advocated the use of appropriate homework assignments. England and Flately [3] and Doyle and Barber [4] have also provided eloquent recommendations for the assignment of homework.

Bloom's Taxonomy of Educational Objectives offers a useful method of categorizing the learning process. Bloom lists <u>knowledge</u> as the lowest level of learning. This level of learning can be easily addressed utilizing a variety of class presentation methods. The next two levels, <u>comprehension</u> and <u>application</u>, can also be addressed through the class presentation but generally require somewhat more effort. However, the remaining higher three levels of learning, <u>analysis</u>, <u>synthesis</u> and then <u>evaluation</u> are difficult to accomplish during most class sessions. An exception would be a class that actively includes an application section such as lab experimentation or a problem-solving segment

Kolb [5] has characterized learning into four basic preferred styles. Each category defines a method of learning in which a student will remain if given the opportunity. The first category is <u>concrete experience</u> in which learning is based on personal experience and observation of other people. The second category is <u>reflective observation</u> in which ideas are examined from several points of view. The third is <u>abstract conceptualization</u> in which logical analysis and systematic planning is utilized to develop knowledge. The last category is <u>active experimentation</u> in which the learners actively experiment with the parameters to gain a better understanding of the idea under discussion.

Kolb has defined a second aspect to the learning process. He shows that by requiring students to move out of the preferred mode of learning the increase in retained knowledge is dramatic. His recommendation is to help the student move through all four learning styles. Initially just add practice to what has been discussed in class. Then add situations or problems that require analysis, evaluation and experimentation. Both Bloom and Kolb recommend using a variety of assignment tasks to maximize student learning. Depending upon the time available for the assignment, it is possible that more than one objective level and learning mode can be included in a single homework assignment.

In order to consider the various aspects and nuances of new or complicated topics, the student must be allowed time to develop the solution process. Since there is almost never enough time in class to devote to this highly individualistic and personal effort, work outside of class is necessary. The conscientious student will develop a study technique and attempt to achieve Bloom's upper levels of learning. The instructor can help these students as well as those that are not self-starters to progresses through the maze by careful selection of the homework. Careful assignment of homework can help the student understand the topic under examination as well as tie it to the purpose of the course within the program.

Burman [6] shows how dramatic the improvement in student performance in a course that did not previously require outside work can be by adding only two (long) assignments that were turned in and graded. Sokol [7] modified one section of a physics class to include a large homework component. He compared this to a control section and found a significant improvement in student learning due to the assignment and grading of the homework.

Elements of homework assignments

To be maximally effective, design of the individual homework assignments within the program must consider several specific elements. Cooper [2] and Doyle and Barber [4] have carefully defined the elements of homework and their relation to an optimal program. These basic elements are:

A) Careful determination of the assignment elements
B) Sufficient time for the student and the instructor to complete the assignment
C) Collection of the finished assignment
D) Evaluation of the student's performance with quality feedback to the student
E) Evaluation of the teaching performance
F) Expeditious return of the evaluated assignment to the student.

The first element, (**A**), which is the main focus of this paper, is not always given the sufficient attention it warrants. Sometimes, at the end of the class period, an instructor will quickly pick a few problems from the back of the chapter and assign them for homework, a highly inefficient process. The instructor must design the assignment to enable the development of skill in the solution of the new material and to incorporate previously learned techniques into that solution. The assignments must also stretch the student with new and different applications. There are two considerations that should be addressed. First, the instructor has to decide upon the type of assignment that will maximize student learning while addressing the current course topic. Secondly, the assignment should include the course's specific student achievement objectives.

Homework types

Lee and Priutt [8] have defined four principal types of assignments. The simplest type is <u>skill development</u>. Generally the assigned problem situations are very similar to the examples in the text or worked on the blackboard. The student simply applies the demonstrated process that has been memorized. This activity tends to result in surface learning. It does, however, enhance the mental consolidation of the topic just discussed in class. In terms of Bloom's Taxonomy, this would equate to the bottom level, knowledge. This type of problem would generally add to the student's concrete experience learning mode without generating real mastery of the concept.

Skill development is very appropriate for the first assignment of new material. Consider an Applied Statics class that has just finished a segment on rectangular components of a vector. The assignment would be to break a vector into its standard rectangular components and then add another pair of rectangular components into a single resultant vector. After studying the torsional shear stress equation in Strength of Materials, the assignment would define a cylindrical metal bar and ask the students calculate the shear stress or torsion load or length or determine the material.

The second type is <u>preparation</u> in which a problem is assigned that is part of the material to be covered in the next period. With only a very brief introduction, the student is expected to read ahead and complete a problem that is very similar to a text example. This type of problem assures that the student has read the material before class. Just by having read the material and worked a simple but typical application, the student is should be ready for the class discussion.

The amount of time necessary to introduce the topic is greatly reduced and more class time can be spent on the application of the topic. This would necessarily move the student up a notch on Bloom's Taxonomy and push the student towards the reflective observation learning style.

A Statics example would be to enhance the skill development problem above. In this case, assign an additional problem that requires the addition of several vectors that first have to be broken down into rectangular components. For Strength of Materials, the next topic is typically angle of twist. Then, with very little discussion, add the determination of the twist angle to the skill development problem.

The third type of homework is <u>extension</u> in which previously learned material is recalled and incorporated into the solution. This provides a good method to tie the course and academic program material together. Extension assignments would improve the student's learning level past comprehension into application. It would be equivalent to Kolb's abstract conceptualization mode of learning.

In the first chapter of Statics, the review covers simultaneous equations and oblique triangle solutions. Assign a problem with three (3) vectors and require the solution by the rectangular component method, the simultaneous equation method and by a force triangle. Since the students have previously studied stress concentrations in another context in Strength of Materials, add a stress riser to the above torsion problem. This combination would have skill development, preparation and extension homework types in one (large) problem. However, the problem should be structured so that each part is independent, i. e., if the student isn't able to complete the extension portion, it wouldn't prevent accomplishment of the skill or preparation portions of the problem.

The fourth type is <u>integration</u> and is most frequently utilized in lab experiments, group projects and course projects. Homework that addresses integration is more difficult as the student must be able to apply the knowledge to an unfamiliar situation. This is a departure from the text book procedures as successful application requires a more thorough understanding of the topic. The principles to be applied are exactly the same but the situation appears to be very different. This would illustrate the top level of Bloom's Taxonomy and utilization of all four styles of Kolb's learning cycle.

A Statics example would be to place a folding chair on the desk, ask a volunteer to sit in the chair and then have the class determine the force in all of the chair members. Then have a different size volunteer sit in the chair and determine how the force values change. Similarly for Strength of Materials, give each team three metal bars and require them to examine the differences in stress and twist under various loads. Typically, an integration problem would be assigned after the entire topic has already been addressed in the class and practiced.

Learning objectives

For an appropriate assignment, the objectives of that assignment should first be carefully defined. As the definition becomes more explicit, the design of the assignment instrument becomes better focused. The faculty of the MET Department of the Purdue University School of

Technology examined the content and application for each MET course. A minimum level of knowledge that each student should achieve by the end of course was identified. Ideally, these Core Learning Objectives are made available to the students in the class. An example is shown below.

CORE LEARNING OBJECTIVES
MET 111 Applied Statics

Class 2, lab 2, cr. 3 Prerequisite: MA 153, MET 160, corequisite MA 154
Force systems, resultants and equilibrium, trusses, frames, beams, and shear and bending moments are studied. Upon successful completion of this course, the student should be able to:

1. Determine the resultant of several vectors.
2. Calculate the moment of a force by total force and by sum of the component forces.
3. Calculate the moment of a couple.
4. Replace a given couple with an equivalent couple system at another location.
5. Draw complete free-body diagrams of whole mechanisms or parts of mechanisms.
6. Apply the equations of equilibrium to free-body diagrams.
7. Calculate the axial load in truss members using (a) the method of pins and (b) the method of sections.
8. Calculate the pin reactions for various mechanisms and frames using the method of members.
9. Apply the friction laws for dry surfaces.
10. Determine if motion is (a) impending slipping or (b) impending tipping.
11. Locate the centroid of a (a) composite area and (b) a composite line.
12. Construct complete load-shear-bending moment diagrams using the slope-area method.

The second element of homework design, (**B**), requires the instructor to evaluate the amount of time necessary for the student to complete the work. Doyle and Barber [4] noted that instructors almost always underestimate the amount of time required to complete the assignment. There must be enough time for all of the students to study the material and do the problems. Bear in mind that if the slower students really don't think they have enough time to do the assignments, they may give up on doing them at all. This would be an opportunity for the instructor design an intervention action to help the slower students come up to speed. Then the class work and homework assignments can advance to higher level learning opportunities. The other classes in which the student is also enrolled require time for studying and homework. Therefore, consideration of these factors forces the magnitude of the assignment to be reduced as much as possible but still sufficient to be useful.

For an expectation that the students, especially those that are performing poorly, will do the assigned work, then the homework must be collected (**C**). It is the knowledge of this step that can change a passive student into an active learner. There are so many competing demands for the student's time that non-collected homework frequently has very low priority, regardless of the benefit to the student. To compound the problem, the student's perception of the correctness of his hazy mental solution can vary dramatically from what was just presented on the board. This misperception can be quickly recognized through the homework performance and then be corrected.

Each problem should be examined (**D**) for utilization of a correct process as well as the correct answer and any errors that lead to incorrect solutions. To provide maximum benefit to the student, the instructor should take this opportunity to give the student personalized attention. This would take the form of extensive annotation of the student's performance directly on the homework assignment. Not only should the errors be noted, but instances where alternate procedures or techniques that could have been used, and suggestions for clearer presentation or better development of the problem. This information can provide that essential point that allows the student to fully comprehend the topic.

The homework evaluation element presents the most difficult portion of the entire homework process in that few instructors have time to do the entire task. There are several techniques that will reduce the time commitment. One is to use the services of graders, another is to use group assignments and a third technique is to assign group projects that require several class periods to accomplish. Another technique to require the assignment to follow a specific format so that the important elements are easily visible and can be quickly checked

Homework Format

Purpose: Develop and promote good work reporting habits for this class, other college class work and written communication on the job

1) Identification	place in upper right hand area of first page	Name Class Identification Problems this set Due date

2) Problem number on left side – clearly indicated

3) Problem statement - variables, equation, and/or sketch as the start point of the solution, any assumptions or defining statements –- identify all variables by statement or by placement on sketch

4) Initial equation - in variable or word form

5) First value substitution into equation - include subsequent equations as necessary to allow logical development by any reader - not force the reader to assume anything

6) Answer - clearly indicated i.e. boxed or circled, include the variable in question and proper units -- no other information in the answer box

7) Neat appearance - orderly development, easily read, a professional document -- numbers and letters, complete equations, all intermediate results are appropriately identified with proper units. One helpful technique is to outline the solution on scratch paper before solving the problem for your homework report

8) Paper used - recommend the "Engineer's Pad", sold by the bookstore, or some other faint grid paper -- Do not tear a page out of a spiral notebook to turn in for credit

9) Paging - use only one side of the page,-- do not crowd your work as paper normally is not that expensive, number each page of your homework as "page number / total number of pages" i.e. 2/5,-- put the paging the top right corner of each page and staple each homework set together

10) Grading - a judgement value of up to 25% of the grade will be deducted for report quality i.e. for a 20 point homework, up to 3 points - the difference between an A and a B

By reviewing the performance on the assignment of the class as a whole, the instructor can see areas of general knowledge and understanding or the lack thereof. The instructor should then be able to determine how well the topic was presented, (**E**). There can be a distinct difference between what the student thought he heard and what the instructor thought he said. In order to accomplish the course objectives, the instructor may have to readdress a portion of a previous lecture but from a different perspective.

The last element (**F**) is very important. The impossible task is to return the graded and annotated homework at the end of the period in which it was due. However, the instructor must return the homework in time for the student to apply the additional information gained in the evaluation process. The instructor's comments are sometimes ignored if the student doesn't see how the information in the comments can be immediately and directly applied the to the next assignment or test. Lack of a timely response can result in much of the instructors work going down the drain. The magnitude of the assignment, therefore, must be such that both the student and the instructor have time to complete their part of the assignment.

Record keeping

One method of ensuring that all of the course objectives are adequately addressed is to keep records. By recording each homework assignment by problem number, type of learning to be achieved and the class objective being addressed, a quick glance can reveal a large amount of information about the course. In particular, it is easy to see if all objectives were addressed. A little more analysis is necessary to see if the mix of assignment types was satisfactory to maximize student learning. These forms can also provide the start point of an assessment system. Below is an example of an assignment from a Technology Applied Statics course.

MET 111 HW/TEST # 4

Goals ------------ Problem #	Skill Practice	Preparation	Extension	Integration	Objective #	Concept addressed
P# 2-14	x				#1	Vector addition
P# 2-19	x				#1	Rectangular components
P# 2-21			x		#1	Resolve 2 vectors into components than add to a single vector
P# 2-24		x			#1	Resolve three concurrent vectors into a single vector

Summary

There are a multitude of studies of which the large majority show that a well executed homework program results in higher student learning. It is very gratifying to see a student change from a passive back row sleeper to an active learner with good questions and comments. It is satisfying to see an active learning technique "turn on the light" and remove a student's stumbling block. Other benefits include a decrease in review of previous material and more time to pursue the new material. Occasionally, a student will present a fresh view of an old topic that can be incorporated into future presentations. By evaluating the student work, it is fairly easy to see where the class missed a fairly simple but crucial point in which the instructor had invested insufficient class time. Utilization of the homework application form also makes it easy to see if all of the course requirements were addressed. The development and maintenance of a homework system is time consuming, especially the optimal system described above. However, it is one tool that has been shown to produce a distinct improvement in the student classroom achievement as well as general academic education, which is a primary purpose of the university experience.

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Biography

Lloyd Feldmann received a BSME from the University of Arizona, an MSE from Purdue University and an MA in Adult Education from Ball State University. He served ten years in the U S Navy as a Naval Flight Officer. He then worked eleven years for Cummins Engine Company in a variety of industrial engineering positions. He has also taught as a full-time lecturer in the Mechanical Engineering Technology Department at IUPUI, Columbus campus, for seven years. Currently he is an assistant professor in the MET Department of the Purdue University School of Technology at Columbus. Questions or comments can be directed to (812) 348-7214 or lfeldman@iupui.edu.