Problem Design in Homework

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Abstract

In some engineering courses, such as *Engineering Mechanics* and *Circuit Analysis*, almost all of the basic concepts and laws have been introduced in General Physics. Therefore, the emphasis of these courses is on the methods and skills in problem solving. However, the solution manuals for most textbooks can be downloaded from the internet, and thus many students just copy the solutions without trying to solve the assigned homework problems. If this short-cut approach is not effectively prohibited, these students will learn very little in these courses. When they start to take the following advanced courses, such as *Fluid Mechanics* and *Electronic Circuits*, these students will have tremendous trouble and are likely to fail.

There are a number of approaches that can avoid this problem, such as the flipped classroom. We adopted a new approach: A subgroup of students were asked to redesign the homework problems, and then the altered problems were assigned to the whole class. There are two direct benefits in this approach. First, students cannot find the solutions of these redesigned problems, so they have to work out the solution by themselves. Second, in the designing process students can develop a deeper understanding of the underlying knowledge structure and are empowered in the problem solving process.

Introduction

Unlike physics courses, the emphasis of many engineering courses is on problem solving, rather than understanding the fundamental laws in nature. Although there are debates on the effectiveness of traditional homework in education [1-4], the overwhelming majority of engineering faculty believe that homework is an indispensable component in the courses they teach. There are four instructional goals for homework: practice, preparation, extension and integration [5-7]. As an analogy, nobody can write good essays just by reading a few examples. Therefore, engineering students cannot grasp the knowledge and skills without the process of struggling with homework problems, which is confirmed by research results [8].

Unfortunately, the solution manuals of most textbooks are readily available from the internet, and some students have already developed a bad habit of doing their homework by copying the solutions. Many research results show that this behavior has detrimental effects to students' learning [9-10]. In order to avoid this problem, a few different approaches were proposed and adopted in the past [11-13], such as flipped classroom and individualized homework problem assignments, etc. However, a more effective way in dealing with the challenge of the solution manual being readily available is still missing.

Problem Design

Engineering Mechanics—Dynamics is a required course for most engineering students, and it is a core course for students majoring in Mechanical Engineering. Almost all of the concepts and laws in this course have been introduced in General Physics, such as Newton's laws, energy and momentum, etc. However, students need to learn new methods and approaches to solve engineering problems in this course. In order to prohibit students from copying the solution manual directly, they were asked to redesign the homework problems first, and then these altered problems were assigned to the whole class.

At the beginning of the semester, the students in this class were divided into groups, and they were asked to redesign the problems in turns. In the spring 2017 semester, fourteen students registered for this course, and they were divided into four design groups. For each homework assignment, a design group was selected to redesign the candidate problems from the textbook. More specifically, each student was assigned a problem to design. After they had submitted the redesigned problems, the instructor reviewed them first and then selected three of them as the homework assignment for the whole class. Sometimes the designed problems were flawed, in that case, the instructor needed to revise the redesigned problem.

In order to encourage students to spend more time in designing the problems, it was considered to grade the quality of the designed problems. However, in the course management system (Moodle) used in our university, it is hard to post scores of a subset of students. In addition, the number of problems assigned to each student are slight different, which makes the grading process more complicated. Furthermore, at the beginning students showed signs of low confidence in problem design, and they would become more nervous if their designed problems were graded. In order to further lower the threshold of problem design, students were not asked to provide the solution to their designed problems. In this way, students were given the same amount of credit as long as they submitted a designed problem. It was observed that students' overall confidence level in problem design rose significantly in the second half of the semester.

There is an additional benefit in the problem designing process. Physics laws and theorems can be understood as relationships between different variables. In general, a homework problem works in this way: Some parameters are provided, and students are asked to figure out the missing ones by applying the laws and theorems. For example, if X, Y, and Z are known, find W. In the redesign process, this problem can be revised in this way: If W, X, and Y are known, find Z. Therefore, the activity of problem design can help students realize the relationships among these parameters. In this way, one problem can generate several related problems with the permutation of these parameters.

For example, an automobile tire with known radius of gyration is released from rest at the top of a slope with known height, find its velocity when it reaches the bottom of the slope without slipping. A similar problem is P18-40 in the textbook by Hibbeler [14]. With the principle of mechanical energy conservation, these three parameters are related: radius of gyration, height and final velocity. The original problem provides the first two parameters, and students need to find the last one. By providing different parameters, this problem can be redesigned in two different ways. In addition, an initial velocity can be involved, and a few more versions of this problem can be created. Furthermore, friction loss can also be introduced.

Assessment

We are in a regional public university in a poor rural area, and most students work part-time. Therefore, any extra work in a course is not very popular. At the end of the semester, students were surveyed on this approach. The first question was: "*Is it helpful for your study in working on the redesigned problems rather than the original ones*?" Thirteen students participated in the survey, and the answers were very diverse: five positive, three neutral, four negative, and one without answer. It is understandable that some students did not like this approach, since the short-cut path of copying from the solution manual was blocked and they had to spend extra time and effort in designing and solving the homework problems.

The second question in the survey was: "*Do you feel empowered in designing the homework problems*?" There was almost an even split among the thirteen participated students: seven positive and six negative. As we know, in every class there are a few students not fully engaged in their study, and their objective is passing with the least effort possible. Although they were pushed to redesign the problems, some students just did it in the easiest way, sometimes just changing the numbers of the original problems.

In order to have an objective assessment of the outcome in this approach, the *Mechanics Baseline Test* [15] was used, which has 26 multiple choice questions. This is not the best way to access the progress of learning for this course, since the emphasis of this test is on the basic concepts and theorems. The average score of the pre-test at the beginning of the semester was 15.0, and that of the post-test at the end of the semester was 19.4. On average, 4.4 more questions were answered correctly, which indicated significant progress in learning this course.

Challenge and Proposal

The redesign process caused a delay in homework assignment, and students were not able to work on the problems just covered in the lectures. In addition, reviewing the redesigned problems also takes some extra time and effort for the instructor. In my department the class size is rather small, so the homework is graded by the instructor. However, if the class size is large, it might be challenging for the teaching assistants to handle this situation.

There is a possible solution to this issue: Among the problems in each assignment, students are asked to redesign one of them and then solve their newly designed problem. In this way, the delay is avoided, and they have to be more serious in the design process. In a few years, an instructor can accumulate a large number of redesigned problems, which can be used as homework assignments in the future. This approach also has some drawbacks, such as the heavy work load in doing the homework and the low efficiency in grading, since there are numerous versions of the redesigned problem.

If more instructors adopt this approach, the redesigned problems can be shared. After having accumulated enough redesigned problems, students will no longer need to do the work of problem design. The authors of the textbooks or the publishers can collect the redesigned problems to build up libraries, and they can offer them to the future instructors who adopt the textbooks. However, they should not provide the solutions, otherwise this newer version of solution manual will leak out sooner or later. In addition, artificial intelligence can also be

applied in the redesign process and provide different versions of the problems, and online homework assignment and grading systems can be developed.

Conclusion

Some students have developed a bad habit of doing their homework by copying from solution manuals, which has detrimental effects on their learning. We developed a new approach to meet this challenge: Asking students to redesign the homework problems, and then assigning the altered problems to the whole class. Besides preventing this short-cut approach, there is an additional benefit in the problem designing process: Students can develop a deeper understanding on the underlying knowledge framework and become more confident in solving problems.

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