AC 2007-726: STUDENT USE OF AUTHOR'S TEXTBOOK SOLUTION MANUALS: EFFECT ON STUDENT LEARNING OF MECHANICS FUNDAMENTALS

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Abstract

Evidence indicates 90% of engineering students have used author's textbook solutions manuals, and up to 75% of these students regularly use the manuals when working graded homework assignments.[1] Many faculty intuitively believe that the use of these manuals by students is not only a form of academic dishonesty, but has negative effects on student learning; however the effect on learning is not well documented. In order to assess the effects of solution manual usage, classes in Statics and Dynamics were monitored at California Polytechnic State University, San Luis Obispo. Each of these courses is taught in multiple sections by the same instructor during the same quarter. In this study roughly one half of the sections were given homework problems from the textbook while the other half were give homework problems from other sources. Comparative assessment of student learning included course surveys, homework scores, quizzes, and final exams. Results of the study indicate that the students who attempt the majority of homework assignments without access to solution manuals perform better on exams and earn higher grades in the classes. This paper presents the detailed results with conclusions drawn concerning the effects of student usage of author's textbook solution manuals.

Introduction

Homework is a traditional component of educational programs in general and engineering classes in particular. Engineering professors typically perceive that learning how to apply technical knowledge requires students to complete some problems on their own at their own pace. Some research has been done to document the positive impact of homework on student learning. A review of 15 studies on elementary and secondary students showed that the effects of homework on student learning were large and consistent.[2] If the homework was assigned without feedback, a typical student at the 50^{th} percentile rose to the 60^{th} percentile. If the homework was graded or feedback was provided, the typical student now rose to the 79^{th} percentile. In a subsequent review researchers also found that homework positively impacts student learning and that the impact varies dramatically with grade level.[3] The effect of homework on performance is minimal for elementary students, significant for junior high students, and substantial for high school students. A more recent study focused on the impact of grading versus not grading homework assignments for electrical engineering students in a preparatory math course.[4] The results of this study were less conclusive. For the first semester of the study a significant improvement was measured for the students whose homework was graded, but for the second semester of the study no impact was found. Thus, there is good evidence to support that assigning homework has a positive impact on student learning and reasonable evidence that giving some incentives to complete the homework (such as grading) is also important.

For most college level math, physics, or engineering classes a list of problems that can be assigned for homework are provided at the end of each chapter of the textbook used for the course. For many courses, assigned homework is a prime mechanism for problem solving practice. This method of assigned, collected, and graded homework persists throughout the curriculum from introductory to higher-level classes, some of which also include a laboratory component. The course instructors are usually provided with an author's textbook solution manual where all of the problems are worked out completely. The author's and publisher's intent has generally been to not make this resource available to the students because the problems are often graded and contribute to the student's final grade for the course. Up until about the year 2000 these manuals were only available in hardcopy form, typically as a bound book. Since this time, solution manuals have become available in electronic form, typically as PDF files supplied on a CD-ROM disc with the instructor's copy of the textbook or through a password protected site on the internet. Almost all authors' textbook solution manuals are now published in electronic form.

Anecdotal evidence supplied by faculty in Cal Poly's ME department suggested that many students now have access to these textbook solution manuals and use them to work on their graded homework assignments. To quantify the extent of the usage of author's textbook solution manuals and how they are used a pilot study was conducted at Cal Poly that consisted of administering a survey to students and faculty in the College of Engineering.[1] The surveys were completed by 674 engineering students. The results indicated that 90% of students have used "textbook solution manuals not distributed by the professor for courses at Cal Poly to either help with assigned homework or as a study aid." For eight of the courses surveyed, the textbook solution manual was published in electronic form. For these courses 73% of the students had access to the textbook solution manual for this course. One of the courses surveyed does not use a textbook and homework problems are written by faculty at Cal Poly. Many of these problems are used repeatedly each quarter and 13% of the students surveyed reported having copies of old solutions. Finally, one of the courses surveyed only has the solution manual available in bound form and 9% of the students surveyed reported having copies of old solutions that were distributed by faculty during previous quarters**. Thus, access to textbook solution manuals over the past 5 years has gone from a minority of students having access when they were only available in hardcopy form to a vast majority of students having access because they are now available in electronic form.**

The change in the availability of textbook solution manuals raises several interesting questions. First, do we need to consider if there are any new ethical issues? For example, does using a textbook solution manual when completing a graded homework assignment constitute cheating? The previous study found that most students do not consider this to be cheating except in the extreme case of plagiarism where the solution is copied completely.[1] If instructors disagree with this opinion, now that so many more students have access to the solution manual they need to very clearly communicate this to their students. Second, what is the impact of this change on the effectiveness of homework on student learning? Many faculty in Cal Poly's ME department have expressed concern that if students never attempt textbook problems without first referring to the solution that they are missing a key element of the creative problem solving process. This could negatively impact their performance on tests and as a practicing engineer. The objective of this

paper is to access the impact of using an author's textbook solution manual for completing graded homework assignments on student learning of fundamental mechanics at Cal Poly.

Background

This study is being conducted using fundamental mechanics classes offered at California Polytechnic State University (Cal Poly) located in San Luis Obispo. Cal Poly's College of Engineering has approximately 4,600 undergraduate students, with about 1,000 students enrolled in the Mechanical Engineering (ME) Department. The ME Department has 34 full-time faculty including tenure-track professors and lecturers and offers approximately 30 different courses each quarter, many with multiple sections. A defining feature of Cal Poly's approach to engineering education is giving the students many laboratory intensive, "hands-on" experiences coupled with small lecture class sizes (usually less than 35 students). The purpose of these small lecture classes is to encourage close interactions between instructors and students. A typical junior or senior level class consists of three 50-minute lectures and one three-hour lab experience per week. Introductory courses in mechanics offered by Cal Poly's ME department were selected as the focus for this study because of the large number of sections offered. An introductory class such as Statics, Dynamics, or first a course in Fluid Mechanics or Thermodynamics consists of only the lecture portion. Introductory classes are often required for students in other engineering departments. Due to the large number of students and small class sizes, it is not unusual for the ME department to offer five to eight sections of Statics or Dynamics with two to four different instructors each quarter. The major objectives of these introductory courses are to impart an understanding of the theoretical basics of applied physics and instill in the students a formalized problem solving process. For the majority of the introductory courses, assigned homework is the prime mechanism of problem solving practice.

Design of Study

Homework Matrix

The first set of classes selected for this study was five sections of Statics taught sequentially during the day in the spring quarter of 2006. In an attempt to remove the instructor as a variable in the study, each of the sections was taught by the same person. The first, third and fifth sections were given homework assignments that consisted of problems from the textbook. The second and fourth sections were given a different set of homework problems developed by the authors or taken from a variety of other standard Statics textbooks. The problems were selected to illustrate the same concept or problem solving procedure as the textbook problems assigned in the aforementioned three sections. It is highly unlikely that any student would have a set of author prepared solutions to these problems. Portions of the textbook solution manual related to course content were provided to the students in all sections for reference. The second set of classes used in the study were four sections of Dynamics taught sequentially during the day of the fall quarter 2006 by the same instructor who taught the earlier Statics classes. The second and fourth sections were given problems directly from the textbook. The first and third sections were given a set of problems again either developed by the authors or taken from other Dynamics textbooks. In all classes homework was collected at each class period. The Statics and Dynamics sections consisted of 32 to 36 students.

Survey Design

The direct survey question (DSQ) approach was chosen for this study because of its simplicity. To encourage honesty the student surveys were anonymous. Surveys were administered using a web based instructional tool called "Blackboard" and students were encouraged during class to go to the web site and complete the survey. For the survey administered to the Statics classes during the Spring 2006 quarter, half of the questions were completed during the first two weeks of class and half of the follow up questions were completed during the last week of class. For the survey administered to the Dynamics classes during the Fall 2006 quarter, all of the questions were completed during the last week of class. A total of 16 multiple choice questions were asked on the student surveys. The initial survey questions were used to establish background information such as gender, age, year in school, and department. The remaining survey questions were used to determine the following: (1) time spent on homework for a typical class and this class, (2) time spent on tests for a typical class and this class, (3) preferred method for homework assignments, and (4) preferred contribution of homework towards final grade.

Testing Matrix

Each section of Statics and Dynamics monitored in this study was graded using a combination of homework scores, two midterms, and a final exam. The final exam is common to all sections of Statics or Dynamics and is administered at the same time. The midterms were also identical although administered sequentially throughout the day according to the class meeting time. The homework was graded and accounted for 20% of the student's final score in the class. For all sections, student performance was monitored by tabulating homework, midterm, and final exam scores allowing comparison of performance between sections using homework problems from the textbook and those using homework problems from other sources. In all cases the students had access to the textbook solution manual for reference. The students overall Grade Point Average (GPA) and performance in a prerequisite Physics course was also tabulated. Any student who did not complete the course (either through a formal withdrawal process or by not taking the final exam) was eliminated from the study.

Results and Discussion

Survey

During the Spring 2006 quarter, five sections of Statics participated in this study. Out of a total of 170 students enrolled in all classes, 147 students completed the initial survey (86.5% response rate) and 143 students completed the final survey (84.1% response rate). Mostly engineering students were enrolled (8.8% aerospace, 25.9% civil and environmental, 19.7% mechanical, 42.9% other engineering, and 2.7% non-engineering). The ratio of male to female students was 78.9% to 21.1%. For the students surveyed, 43.5% are under 20, 55.1 % are between 20 and 24, and 1.4% are between 25 and 30 years of age. This is consistent with the "traditional age" student body at Cal Poly and a sophomore level class within the ME curriculum. As expected, the sample consisted of mostly sophomores (15.6% freshmen, 64.6% sophomore, 12.2% junior, 6.1% senior and 1.4% five years or more). Almost all of the students (98.0%) were admitted as freshmen.

During the Fall 2006 quarter, four sections of Dynamics participated in this study. Out of a total of 140 students enrolled in all classes, 117 students completed the survey (83.6% response rate).

Again, mostly engineering students were enrolled (12.0% aerospace, 29.9% civil and environmental, 24.8% mechanical, 32.5% other engineering, and 0.9% non-engineering) and the ratio of male to female students was approximately the same (78.6% to 21.4). For the students surveyed, 10.3% are under 20, 85.5 % are between 20 and 24, and 4.3% are between 25 and 30 years of age. This represents a slightly older group of students than for the Statics classes. Correspondingly, the sample now consisted of mostly juniors (0% freshmen, 14.5% sophomore, 66.7% junior, 15.4% senior, and 1.4% five years or more). Most of the students (76.1%) were admitted as freshmen, but there were a significant number of transfer students in the sample.

The second set of questions asked how much time students spent completing homework each week and preparing for tests for both a typical class at Cal Poly and this class in particular. The average time spent on each based on their responses are given in Table 1 for both Statics and Dynamics. The results are separated into columns for the two cases considered: (1) students who completed homework from the **textbook** where the solution manual was provided and (2) students who completed homework from an **alternate** source where homework solutions were not provided until after the problems were due. For both Statics and Dynamics, students reported spending about 0.4 hours/week more on homework for these classes than other classes at Cal Poly. Also, they spend about 0.3 hours/week more on Dynamics homework than Statics homework. Comparing students who used textbook verses alternate source problems, for both Statics and Dynamics using the alternate source problems resulted in an increase of about 0.15 hours/week spent on homework. The amount of time required to study for each test for this class compared to a typical class at Cal Poly increased by about 0.5 hours for Statics, but decreased by about 0.4 hours for Dynamics. There were no significant differences for time required to study for tests between students who used textbook verses alternate source problems.

Table 1. Average time in hours spent on homework and tests.

	Statics		Dynamics		
	Textbook	Alternate	Textbook	Alternate	Avg.
HW for typical class	3.0	2.7	3.3	3.1	3.0
HW for this class	3.3	3.4	3.5	3.7	3.4
Tests for typical class	3.1	3.2	3.6	3.6	3.4
Tests for this class	3.6	3.6	3.3	3.1	3.4

The third question asked students to choose their preferred method for assigning and grading homework. The five different options are listed in Table 2 and the student's preferences are listed in Table 3. The most popular option is consistently Case 2 where the homework is assigned from the textbook, graded, and the solutions are made available before they are due. The second most popular choice is Case 4 which is similar to Case 2 except the homework is no longer graded. Comparing students who used textbook verses alternate source problems, the biggest shift is seen as an increase in students choosing Case 5. **Thus, a larger percentage of students (an increase of about 20%) who used the homework from alternate sources with no solutions available did believe after taking the class that this was a good method for completing and grading homework.** Finally, students were asked how much should engineering assignments count towards your final grade. The average response was 19.5% for Statics and 21.6% for Dynamics.

Table 2. Cases for assigning and grading homework considered.

Case 1	Textbook	Graded	No solutions before due
Case 2	Textbook	Graded	Solutions available before due
Case 3	Textbook	Not graded	No solutions before due
Case 4	Textbook	Not graded	Solutions available before due
Case 5	Alternate	Graded	No solutions before due

Table 3. Student's preferred method for assigning and grading homework.

	Statics		Dynamics		
	Textbook	Alternate	Textbook	Alternate	Avg.
Case 1	7.7%	7.4%	0.0%	1.7%	4.2%
Case 2	76.3%	52.3%	67.4%	62.3%	64.6%
Case 3	0.0%	4.0%	5.4%	0.0%	2.4%
Case 4	13.6%	14.3%	21.8%	13.2%	15.7%
Case 5	2.3%	22.0%	5.3%	22.8%	13.1%

Testing

Table 4 contains the number of students, overall GPAs, average GPAs of a prerequisite Physics course in mechanics, homework completion rates, and test scores for all students who completed either the Statics or Dynamics classes included in this study. For Statics, the students working textbook homework problems entered the class with higher overall GPAs and Physics GPAs than the students who were assigned alternate homework problems. Despite this, these students were able to score slightly better on the exams. The students working non-textbook homework problems turned in a slightly lower amount of assignments which resulted in a lower average homework score. In Dynamics the students working the non-textbook homework entered with higher GPAs and on average scored higher (by 8.7%) on the first midterm and slightly better on the second midterm and final. As with the Statics, these students turned in slightly less completed homework assignments and had a lower average homework score for the class.

Table 4. Comparison of Average Test Results for All Students in the Sections Studied

	Statics		Dynamics	
	Textbook Homework	Alternate Homework	Textbook Homework	Alternate Homework
Number of Students	101	59	63	70
Overall GPA	2.83	2.67	2.79	3.01
Physics GPA	2.48	2.36	2.45	2.56
% of Completed Homework Assignments	84.3%	81.5%	85.7%	83.4%
Homework Score	83.0%	78.3%	82.2%	77.3%
Midterm #1	69.2%	73.0%	57.9%	66.6%
Midterm #2	61.7%	63.4%	53.0%	54.6%
Common Final	57.6%	58.0%	57.3%	60.5%
Class GPA	2.11	2.12	2.09	2.33

Based on the results of Table 4, one could claim some benefit from not using textbook solution manuals for the overall class of Statics students, but the benefit to the Dynamics students is

unclear. Another look at the data can be made by eliminating any student who did not complete the homework assignments on a regular basis. Table 5 shows average class performance including only those students who completed at least 80% of the assigned homework assignments and completed the entire course. By eliminating those students who did not turn in most of the homework, it becomes clear that the students who worked problems without access to solution manuals scored higher in these classes as evidenced by the significantly higher class GPA and average exam scores. Anecdotal evidence from the course instructor shows that a much higher percentage of office hour visitors were students from sections with non-textbook homework assignments. This would indicate that students with textbook problems would reference the solutions manuals instead of asking questions of the instructor.

Table 5. Comparison of Average Test Results for Students who Completed 80% or More Homework Assignments

	Statics		Dynamics	
	Textbook Homework	Alternate Homework	Textbook Homework	Alternate Homework
Number of Students	75	40	52	53
Overall GPA	2.89	2.77	2.84	3.08
Physics GPA	2.74	2.49	2.49	2.74
% of Completed Homework Assignments	94.7%	94.2%	94.1%	95.7%
Homework Score	92.2%	88.9%	89.4%	88.1%
Midterm #1	68.4%	74.6%	56.8%	68.9%
Midterm #2	63.4%	65.4%	53.2%	55.7%
Common Final	58.0%	61.3%	58.0%	63.4%
Class GPA	2.21	**2.50**	2.20	**2.65**

Conclusions and Future Research

This study attempted to ascertain the affect of student use of author's textbook solutions manuals on learning in basic engineering courses by taking nearly identical sections of Statics and Dynamics and giving some homework problems assigned from the textbook and others an alternate set of problems. Student survey results indicated that they did not spend a significant increase in time working homework problems from a non-textbook source and that a majority of students desire to have graded homework with access to solutions prior to turning in their work. It is interesting to note that a higher percentage of students in the sections without textbook problems believe it is better to not have solutions (see Table 3, Case 5). In terms of class performance and considering only students who did greater than 80% of the homework, students who had non-textbook problems and therefore no access to solutions, performed better on exams and earned higher grades in the classes (see Table 5). Instructors who are aware of student use of textbook solution manuals may want to consider these results as evidence of the negative consequences of their use at the same time, they should also be aware of the large time commitment involved in providing alternate homework problems. Improvements to this work would include a larger sample size and the use of other assessment methods besides test scores such as concept inventories to measure outcomes. The authors plan to expand the study to include more students as well as track students longitudinally to see if changes in study habits

and performance can be found by limiting textbook solution manuals as a resource for solving graded homework assignments.

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