Impact of Publisher-Provided Course Materials and Related Pedagogy on Student Learning in a Sophomore Statics Course

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Abstract

At Loyola University Maryland, Statics (EG301) is taught to first-semester sophomores as one of their foundational engineering courses. The popular textbook by Hibbeler [1] has been used for some time, and prior to 2010, instructors taught this course using a traditional lecture/whiteboard approach. Overall student performance was generally good, but in an attempt to improve student learning, the author adopted a modified version of the PowerPoint® slides that accompany Hibbeler's textbook beginning in 2010. This paper describes the impact of using these slides (and the attendant instructional approach) on student performance and perceived learning.

Two student cohorts were considered: (1) the 2005 and 2009 classes (47 students), who were taught by the author using the traditional method; and (2) the 2010 and 2011 classes (42 students), who were taught by the author using the revised method. Student performance was assessed by examining the Statics grade distributions in each cohort as well as the final exam scores. (The same final exam was administered to each class.) In addition, perceived learning was assessed via questionnaires that asked the students to evaluate their proficiency relative to seven specific course learning objectives. Student grades in freshman Calculus and Physics were also examined to help identify *a priori* differences in cohort capabilities.

Overall, quantitative analysis suggests that the revised approach did not significantly improve student learning. In fact a decrease in student performance was calculated, though this difference was not found to be statistically significant. The students did indicate via written comments that they considered the revised approach to be helpful in their studies. Reasons for these results are discussed, and possible changes to improve the impact of the revised approach on student performance are provided.

Introduction

The majority of engineering curricula include a course that applies the concepts of Newtonian mechanics, vector analysis, and calculus to analyze stationary rigid bodies—often referred to as Statics. This subject is frequently taught using a "traditional" approach where the instructor lectures to students about key concepts and works a large number of example problems at the board while students take notes. Perhaps because the subject is taken by so many engineering students across multiple disciplines, a number of investigators have developed and examined innovative teaching strategies for improving student learning in Statics. (See, for example, [2-4].)

There are several well-established textbooks for Statics, one of which is *Engineering Mechanics: Statics* by R.C. Hibbeler [1]. To assist the instructor, a set of PowerPoint® slides that are linked to the textbook can be downloaded from the publisher's website. These slides were originally created by Danielson and Mehta as part of a National Science Foundation (NSF) Course Curriculum and Laboratory Improvement (CCLI) Program grant to develop resource materials that leveraged relatively recent advances in educational theories and practices [5]. They have since been revised by Mehta, Danielson, and Berg [6].

At Loyola University Maryland, Statics (EG301) is taught to first-semester sophomores as one of their foundational engineering courses. Loyola's program includes concentrations in electrical, computer, mechanical, and materials engineering, but students are not required to select their concentrations at this point in the curriculum, and all engineering students, regardless of their future concentration, take Statics. Hibbeler's book has been used as the course text for some time.

A set of seven learning objectives has been established for the course:

> At the completion of the course, students will have demonstrated the ability to
>
> 1) express force and position in Cartesian vector form and perform basic vector operations including addition, resolution into components, and dot and cross products;
> 2) calculate force system resultants;
> 3) solve particle and rigid-body equilibrium problems using free-body diagrams and the equations of equilibrium in two and three dimensions;
> 4) solve rigid-body equilibrium problems that include forces associated with dry friction;
> 5) determine internal forces and bending moments in beams and members of trusses, frames, and machines;
> 6) evaluate the location of the centroid and the moment of inertia of an area;
> 7) interpret word-based engineering problems, select appropriate approaches for analysis, and devise clear and organized solutions to such problems.

Prior to 2010, instructors at Loyola taught this course using a traditional lecture/whiteboard approach. Overall student performance was generally good, but in an attempt to improve student learning, the author adopted a modified version of the PowerPoint® slides provided by the publisher (Prentice Hall) beginning in 2010. This paper describes the impact of using these slides (and the attendant instructional approach) on student performance and perceived learning.

Traditional Approach to Statics Instruction at Loyola

The author taught Statics in 2005 and 2009 to classes of 21 and 26 students using a relatively traditional teaching approach. The course met for three 50-minute periods each week. During class, the instructor presented theory, concepts, and applications using a lecture format and a whiteboard. Students were asked to read the relevant portions of the textbook beforehand and took written notes as the class unfolded. Multiple example problems were worked at the board by the instructor to illustrate the application of theory to problem-solving. The instructor encouraged student engagement by posing questions and soliciting and discussing responses periodically during each class. Weekly problem sets were assigned as homework which required that the students put into practice the concepts explored previously during class time. These problem sets were collected and scored by the instructor and returned to the students with comments. The final course grade was determined from student performance on three tests (two in-class and one take-home), the homework, and the final exam. A small in-class participation component was also included, based primarily on class attendance.

Revised Approach to Statics Instruction

The author taught Statics again in 2010 and 2011 to classes of 22 and 20 students using materials that were adapted from those provided by the publisher [6]. The motivation for developing these materials was to "enhance the student's learning and understanding of Statics" by incorporating a variety of pedagogical elements that have been found to be effective in the modern educational literature [5,7,8]. The developers used Kolb's Learning Style Model [9] as the underlying basis for the materials, and the slides for each class follow a specific format that includes

- student grading of prior homework;
- well-defined student learning objectives;
- a short, multiple-choice pre-quiz based on the assigned reading (2-3 questions);
- real-life introductory applications of the day's topic;
- a mini-lecture presenting the relevant concepts and theory;
- one or more example problems;
- a short, multiple-choice "concept" quiz to test understanding (2-3 questions);
- a group problem-solving exercise; and
- a short, multiple-choice "attention" quiz to assess final understanding (2-3 questions).

A mapping of these items and activities to the four elements of Kolb's cycle (concrete experience, reflective observation, abstract conceptualization, and active experimentation) is given in [5].

The developers have recommended a detailed implementation strategy for using their materials in a 50-minute class [5]. After running into time constraint problems, the current author modified this strategy as follows:

- In-class grading of student homework was not performed. Danielson and Mehta recommend having students exchange two to three assigned homework problems with their neighbors who then score the problems as the instructor goes over the solutions in class. Instead, the students turned in their homework each week, and the instructor provided written feedback to them.
- The pre-quiz, concept quiz, and attention quiz were not collected. Instead, the quiz questions were posed to the class as a whole, and the students' thoughts and responses were discussed before the correct answer was identified. It was found that administering the quiz for collection took too much time and that the class generally engaged the questions well without collection.

In addition, the slides were modified to improve clarity or to emphasize certain portions of the subject matter. These modifications were numerous but not extensive, and the majority of the content, as well as the framework for instruction, remained intact. In this paper, this is referred to as the revised teaching approach.

As suggested in [5], the students were provided with a set of notes at the beginning of the course. The intent in providing these notes is to free the students from having to copy down all the material presented by the instructor, instead allowing them to annotate key points and think about the material during class. The notes included much of the content from the presentation slides with a few key differences:

- The quizzes were not included in the notes. Given that the quizzes were not collected for grade, this was not necessary, but having the quiz questions only presented in-class may have sharpened student focus toward them.
- Some key equations and definitions were omitted. Having the students add this information to their notes was intended to help solidify their familiarity with it and to further encourage engagement during class.
- The solutions to the group problem solving exercises were not included. The students completed this portion of the notes as they solved the problems in class.

As in the traditional approach, weekly homework sets were assigned, collected, and graded. The overall course grade was determined via the same combination of tests, homework, and in-class participation used in the traditional approach.

The revised approach differs from the traditional approach in several ways including the presentation of real-world applications up front and the explicit use of short quizzes to test student understanding. However, the author already used practical examples and informal questioning to draw students into the subject matter, so this change was not dramatic. Probably the most significant difference between the traditional and revised approaches was the inclusion of a group problem-solving exercises. Students were allowed to work alone or with one of their neighbors to solve these problems. The instructor circulated around the room, coaching the students, before ultimately presenting a solution so that they could check their work. Another important difference was the use of pre-printed notes, which allowed the students to focus more on understanding the material rather than on writing everything down.

Cohort Characteristics

Cohort T (traditional) consisted of 47 students from two Statics classes (fall 2005 and fall 2009), each of whom was taught using the traditional approach by the author. There were 10 females and 37 males.

Cohort R (revised) consisted of 42 students (19 females and 23 males) from our two most-recent Statics classes (fall 2010 and fall 2011). Both classes were taught by the author using the revised approach.

Because there is always the possibility that one cohort happens to be more academically adept than the other, the prior academic performance of each cohort was examined in terms of their grade point average (GPA) in prerequisite mathematics and science courses, specifically, Calculus I (MA251), Calculus II (MA252), Physics I (PH201), and Physics II (PH202). The GPA for these courses was calculated using the following four-point scale:

A	4.000	B	3.000	C	2.000	D	1.000
A–	3.667	B–	2.667	C–	1.667	F	0.000
B+	3.333	C+	2.333.	D+	1.333		

A summary of the cohort characteristics is presented in Table 1.

Table 1. Cohort Characteristics

Cohort Identifier	Instructional Approach	Number of Students			GPA in Prior Courses*	
		Male	Female	Total	Mean	Std. Dev.
T	Traditional	37	10	47	2.86	0.82
R	Revised	23	19	42	3.09	0.69

* prior courses refer to prerequisite courses in mathematics and science

A two-tailed Student's t-test was applied to the prerequisite grade datasets, and the P-value was found to be 0.182, indicating that the difference in mean GPA between the two cohorts is not statistically significant (assuming a significance threshold of $P = 0.05$). Hence, the two cohorts may be considered academically comparable.

Results

Two primary measures were examined to determine the impact of the revised instructional approach on student performance: (1) the mean GPA of each cohort calculated using only the Statics final course grades, and (2) the mean final exam score of each cohort in Statics. All students took identical final exams across all years and cohorts, and the GPA values were calculated using the four-point scale presented earlier in this paper.

The results for these measures are presented in Table 2. The two measures of student performance in Statics—course GPA and final exam score—were each *lower* for cohort R (revised) than for cohort T (traditional).

Table 2. Comparison of Cohort Performance

Cohort	GPA in Statics		Final Exam Score	
	Mean	Std. Dev.	Mean	Std. Dev.
T	2.99	0.84	76.4	12.3
R	2.93	0.93	73.2	17.2

These results are amplified when the performance of each cohort in prerequisite mathematics and science courses is considered, as indicated by the column labeled "Difference" in Table 3. These values represent the difference between the prerequisite mean GPA and the Statics mean GPA. For the T-cohort, the Statics GPA is 0.13 higher than the prerequisite GPA. In contrast, the R-cohort's Statics GPA was 0.15 *lower* than that in their prerequisite courses. This is the opposite of what might be expected based on prior performance. In other words, the R-cohort had better performance in their prior mathematics and science courses than the T-cohort so, all other factors being equal, one would expect them to perform better in Statics, but this was not the case. (These comments are made with an understanding that the difference in cohort performance in prerequisite courses was already shown via t-test to be statistically insignificant.)

Table 3. Cohort GPA in Prerequisite Courses and Statics

Cohort	Mean GPA		
	Prerequisite Courses	Statics	Difference
T	2.86	2.99	+ 0.13
R	3.08	2.93	– 0.15

A two-tailed t-test was also applied to the Statics grades and final exam scores shown in Table 2 to determine whether the differences in average values between the two cohorts had meaning. In terms of the Statics GPA, the P-value was 0.787, clearly indicating that the difference in mean Statics GPA values was not statistically significant. Similarly, when the t-test was applied to the final exam data, a value of $P = 0.332$ was obtained, again suggesting that the mean student performance was not significantly different for the two cohorts. Thus, although a decrease in performance associated with the revised approach was calculated, this decrease was not large enough to be deemed statistically relevant for either measure.

A more indirect indicator of student learning was also considered. As mentioned in the introduction, the Statics course has seven well-defined learning objectives. At the end of the course, the students are asked to complete a questionnaire in which they rate how confident they are in their ability to demonstrate mastery of each objective using a five-point scale (1 – low confidence; 5 – high confidence). The average score over all objectives for cohort T was 4.26 while that for cohort R was 4.20. In general, the students indicated a relatively high level of self-assessed proficiency in both cases, with almost no difference between the overall averages, though the R-cohort score was again lower.

In these questionnaires, the students were also asked to comment on how the course was conducted and to make suggestions as to how it could be improved. In general, the students from cohort R viewed the revised approach very favorably. Especially noteworthy was their approval of the in-class problem-solving exercises, which they said allowed them to put the class material to work immediately. They also commented favorably on the in-class quizzes, which they said helped them reflect on their level of understanding, as well as the class notes, which they found helpful during preparation for tests. However, it should be noted that the comments from cohort T in reference to the traditional approach were also generally positive, indicating that many students still find a traditional lecture approach to be effective.

Conclusions

The primary conclusion of this study is that the use of publisher-provided teaching resources and a modified learning environment did not result in an increase in student performance in Statics. The reasons for this result are not clear. Student comments regarding the revised approach were very positive, so it does not appear that they were uncomfortable with the methods and organizational structure used.

It is possible that Statics is a subject that simply lends itself well to the traditional teaching approach. Modifications to include more active learning strategies may not be significantly more effective relative to improving student performance. It is also possible that the majority of learning currently takes place outside of class when the students read the text and work through their homework sets. In this regard, the two cohorts were treated identically. In fact, though there were differences in the approaches, the changes were not radical, and the traditional and revised approaches, as implemented here, were more alike than different. This could account for the lack of a meaningful impact. Adapting the revised approach for other courses that are not as well-suited to the traditional teaching approach might be a better avenue to pursue.

Another possibility is that the two aspects of the implementations strategy proposed in [5] that were not adopted—student grading of homework in class and collection of quizzes for grading—could have yielded better results. Similarly, innovations other than those included in Mehta, Danielson, and Berg's materials might be more appropriate and effective for this subject. References 2 through 4 describe such possible innovations.

Statistical analysis indicated that the *decrease* in mean student performance calculated for the revised approach was not mathematically significant. Nevertheless, that does not prove that the decrease was not real; it just means that it was well within the expected range of variation associated with these datasets. It is possible that having most of the class notes pre-printed actually resulted in a decrease in student assimilation and retention of material, but this is conjecture, and the author (instructor), who has been teaching for 13 years, did not have the sense that the R-cohort was any less engaged than the T-cohort.

Because the students responded favorably to the revised method, and because student performance was found to be statistically equivalent to that for the traditional method, the author plans to continue the use of the revised method but will make adjustments in the course materials intended to improve their effectiveness. These adjustments will include the omission of more material from the notes to further encourage student engagement during class. The idea is to find the right balance between what is provided directly and what must be added as it is discussed.

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