Quantitative Impact of Textbook Companion PowerPoint® Slides and Related Instructional Approach on Student Learning in Statics

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Abstract

At Loyola University Maryland, Statics 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 first 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 first author using the traditional method; and (2) the 2010 and 2011 classes (42 students), who were taught by the first 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.

Quantitative analysis revealed that the revised teaching approach did not have a statistically significant effect on either the final course grade or the final exam score in Statics. This was true for both male and female students. The revised approach also had no statistically significant effect on the level of perceived learning indicated in numerical student self-assessment surveys. The students did indicate via written comments that they considered the revised approach to be effective and helpful in their studies. Possible reasons for these results are discussed, and changes intended to improve the impact of the revised approach on student performance are provided.

Introduction

Most undergraduate engineering curricula in the United States include a course that applies the concepts of Newtonian mechanics, vector analysis, and calculus to analyze forces on 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[2-9]. Some of these strategies have included the use of PowerPoint® slides as one component of an effective instructional approach.

The use of PowerPoint® in university instruction is widespread, and guidelines abound for creating effective slides that are intended to facilitate student engagement and learning[10-13]. That said, there is some disagreement among investigators as to the impact of a PowerPoint®-based teaching approach. As discussed by Brock and Joglekar[12], when PowerPoint® slides were used in courses, investigators reported both increases and decreases in student engagement, as well as no real improvement in student performance or understanding of material. Daniels[10] also indicated that no significant change in student performance was observed when desktop presentation programs (such as PowerPoint®) were used, but student reaction to the presentation materials was overwhelmingly positive. (The current authors suggest that some of these mixed results could have less to do with the mere use of PowerPoint® and more to do with *how* it is used, but this is not discernible from the literature cited here.) In any event, with at best inconsistent evidence of enhanced student learning, PowerPoint® use remains ubiquitous.

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 companion 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[14]. They have since been revised by Mehta, Danielson, and Berg[15].

First-semester sophomores at Loyola University Maryland take Statics (EG301) as one of their foundational engineering courses. The engineering 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 taught this course using a traditional lecture/whiteboard approach. Overall student performance was generally good, but in an attempt to improve student learning, the first 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

The first 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 first author taught Statics again in 2010 and 2011 to classes of 22 and 20 students using presentation materials that were adapted from those provided by the textbook 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[14,16,17]. The developers used Kolb's Learning Style Model[18] as the underlying basis for the materials, and the slides for each class meeting align with 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 Reference 14.

The developers have recommended a detailed implementation strategy for using their materials in a 50-minute class[14]. After quickly running into time constraint problems, the first author of this paper 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 Reference 14, 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, omitting them from the notes 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 systematic presentation of real-world applications up front and the explicit use of short quizzes to test student understanding. However, the first 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 the group problem-solving exercises. Students were allowed to work alone or with 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 during class.

Student Cohort Characteristics

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

Cohort R (revised approach) consisted of 42 students (19 females and 23 males) from two more-recent Statics classes (fall 2010 and fall 2011). Both classes were taught by the first 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, Calculus II, Physics I, and Physics II. 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 level of $\alpha = 0.05$). Hence, the two cohorts may be considered academically comparable (assuming that performance in these prerequisite courses is a good measure of academic proficiency).

Statistical Methods

Since two classes (years) were nested within the teaching approaches, the data were analyzed using a nested analysis of variance (ANOVA) model. For all variables, it was found that there was no statistically significant difference between the classes. Consequently, this term was omitted from the model, which reduces to a two sample comparison between the two teaching approaches. Covariates were also included in the models to determine if controlling for these additional factors modified the effect of the teaching approach.

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, the GPA values were calculated using the four-point scale presented earlier in this paper. (Students could review their graded final exams in person, but the exams were retained by the instructor to minimize the possibility that future students would become familiar with the exam questions.)

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

	GPA in Statics		Final Exam Score	
Cohort	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

	Mean GPA		
Cohort	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 significant for either measure.

The analyses just described were reported in an earlier "in-progress" regional conference paper[19]. A more-detailed analysis was subsequently conducted to determine whether any statistically significant associations could be identified between specific cohort characteristics and the response variables (Statics course GPA and Statics final exam score). These characteristics included grade in each prerequisite course, year the course was taken, and gender, and they were included as covariates in the ANOVA models. Interactions of teaching approach with each covariate were also included to see if the relationship of the covariates to the response variables differed between the two teaching approaches. It was again found that the instructional method did not have a statistically significant effect on either the Statics GPA or the Statics final exam score, even after "adjusting" for the covariates. Gender and course year were also found to be non-significant. The GPA in prerequisite courses did have a significant effect on the two response variables. For a unit change in prerequisite GPA, the Statics GPA increased by 0.84 (P-value < 0.0001) (on average, while holding other variables constant). For a unit change in prerequisite GPA, the final exam score increased by 9.96 (P-value < 0.0001) (on average, while holding other variables constant). This supported the previous assumption that student performance in these prerequisite courses was a good predictive measure of academic proficiency relative to Statics.

An 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 were asked to complete a questionnaire in which they rated how confident they were in their ability to demonstrate mastery of each objective using a five-point scale (1 – low confidence; 5 – high confidence). A two-sample t-test of the means was conducted for each objective, and the results are summarized in Table 4. In six of the seven objectives (1 – 5 and 7), the P-value is well-above the significance level of 0.05, indicating that the revised method did not lead to higher student confidence in their abilities. The P-value for Objective 6, however, was much lower (0.084), though still not statistically significant by our criteria. This objective relates to the determination of centroids and moments of inertia, and this result suggests that a more thorough examination of the impact of the revised method in this area may be in order.

The students were also asked in the questionnaires to comment qualitatively on how the course was conducted and to make suggestions as to how it could be improved. When asked "Were the PowerPoint® slides (and the way they were used) an effective way to present the course material?" 100 percent of the 37 respondents from the R-cohort responded in the affirmative. Some students made additional comments, which included the following:

- The in-class problem-solving exercises allowed them to put the new material to work immediately (4 students).
- The in-class quiz questions helped them reflect on their level of understanding (3 students).
- The class notes were valuable when working homework problems and preparing for tests because they summarized and organized the material succinctly (3 students).

Two respondents also suggested that the notes be modified to include more places where material needed to be filled in by the students to improve their engagement.

For comparison, 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 found a traditional lecture approach to be effective for this course.

Table 4. Student Self-Assessment of Proficiency Relative to Learning Objectives*

	Mean Score		
Objective	Cohort T	Cohort R	P-Value
1	4.72	4.78	0.592
2	4.61	4.64	0.837
3	4.50	4.39	0.543
4	4.00	4.00	1.000
5	4.06	4.03	0.896
6	3.69	4.06	0.084
7	3.81	4.03	0.231

* scale runs from 1 (low proficiency) to 5 (high proficiency)

Conclusions

The primary conclusion of this study is that the use of publisher-provided presentation slides 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 written 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 reasonably well to the traditional teaching approach. Modifications to include more active-learning strategies may not be significantly more effective relative to improving overall 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 Reference 14 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 9 describe such possible innovations, which were not investigated here.

Statistical analysis indicated that the measured *decrease* in mean student performance calculated for the revised approach was not statistically 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 first author (instructor), who has been teaching for 14 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 in their written comments, and because student performance was found to be statistically equivalent to that for the traditional method, the first 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, in this regard, is to find the right balance between what is provided directly and what should be added as it is discussed.

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