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Online Teaching of Engineering Statistics: A Comparative Case Study*

CAN B. AKTAŞ
Department of Mechanical, Civil, and Environmental Engineering, University of New Haven, West Haven, CT, USA.
E-mail: caktas@newhaven.edu

YILDIRIM OMURTAG
Department of Engineering, Robert Morris University, Pittsburgh, PA, USA

Various forms of online education are rapidly gaining ground in higher education institutions. Engineering programs lag behind in online education due to presumed difficulties associated with online lecturing of mathematics based courses. The goal of the study was to investigate whether there was a significant difference in the mean grades of students enrolled in two sections of a mathematics based Engineering Statistics course offered to undergraduate engineering students. While the course content covered in the two sections was identical, the medium of teaching was different in the two sections: one section carried out a traditional in-class lecture style whereas the other section employed a partially-online type of teaching. Thus, the intention was to explore if the two lecturing styles were equally effective with regard to student learning or if one was better than the other. Results from two sections were compared by using statistical methods and hypothesis tests. Students in the two sections resulted in similar mean values for course credits completed and cumulative grade point average, indicating that there was not a significant difference among student bodies in the two sections. While the dispersion of grades in the partially-online section was higher compared with the in-class lectured section, mean grades came out to be almost exactly the same, a result also supported by the hypothesis test conducted. Results indicate that there was not a significant difference in student grades, taken as indicative of their learning, when the two sections representing different styles of lecturing were compared. Results show promise with respect to the potential for online teaching of Engineering Statistics courses, as well as other mathematics based engineering courses.

Keywords: online education; blended education; engineering statistics; hypothesis test

1. Introduction

Higher education is going through a transition phase where the style and medium of teaching is rapidly changing. Most colleges and universities within the United States now offer multiple online courses within various disciplines. A few have based their entire curriculum on online teaching. As demand increases, it is possible to see more programs shifting to online courses rather than the traditional way of lecturing in-class.

In light of such changes, the Department of Engineering at a private university in the United States decided to initiate online teaching by piloting the Engineering Statistics course during the Spring 2012 semester. Although there have been other fully or partially-online courses offered within the university, this was the first online based course offered through the Department of Engineering in a mathematics based course.

The goal of the study was to investigate if the two methods of teaching were equally effective with regard to student learning or if one was better than the other. Grades of students enrolled in two sections of an Engineering Statistics course offered to undergraduate engineering students were analyzed to determine whether there was a significant difference in mean grades. Although the course content covered in the two sections was identical, the medium of teaching was different: one section carried out a traditional lecture style whereas the other section employed a partially-online, or 'blended' type of teaching. Herein, we report our experiences with the introduction of a partially-online course. Methods and tools employed for the partially-online section have been reported in detail to guide other practitioners and researchers. Quantitative results of a direct comparison of student performance in the two sections supported by statistical analysis were presented.

To take into account the learning curve associated with transitioning from a traditional lecture style course to an online course, the course was offered as a partially-online course during the Spring 2012 semester. Results presented in this study are for this semester only. Having gained enough experience with the online aspect of the course, the Engineering Statistics course was planned to be offered as a fully-online course for the Fall 2012 semester.

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2. Background information

2.1 Online education

Online education is becoming prevalent in all disciplines of higher education. The number of students enrolled in at least one online course has almost doubled from 2.35 million in 2004 to 4.6 million in 2008, and has reached 6.1 million in Fall 2010 [1–4]. The rate of increase in the number of online enrollments far exceeds the rate of increase in total higher education student population. Nearly two thirds of surveyed higher education institutions stated that online education was critical to their long-term strategy [4]. However, faculty acceptance of online education seems to be a barrier in further progress for its application [4, 5]. Analyzing the results of a large-scale survey, Tanner [6] has concluded that faculty perceptions toward online learning are significantly less favorable than students' perceptions.

Learning and teaching are both multi-factorial, depending on but not limited to the experience of the instructor, course subject being taught, or student interest in the course subject. There is little consensus as to which variables should be used to test student learning, and whether online teaching is more effective than traditional in-class teaching. While some studies conclude that there is no significant difference in student learning [7–9], others have found that online lecturing improves student learning [10–13]. However, one should avoid drawing overarching conclusions as integrating comparative studies on online courses is difficult due to differences in the degree of online lecturing with the methods and tools used, as well as the discipline of the course subject [14]. Reynolds [15] reported that partially-online education improved student learning and exam grades, whereas Wellington [16] focused on adding an online component to a traditional course as a supplement, and reported that student participation and exam grades had decreased. In order to provide transparency and repeatability, methods used in the partially-online course have been described in detail.

Wilson [17] reports the importance of additional contact between the instructor and students in an online lecture setting in the form of electronic deadline reminders, progress updates, or through discussion boards and forums, as students with marginal cumulative GPAs may diverge from the topic that could lead to an increased withdrawal rate. While observing positive outcomes, Dutton [13] also reported on the decreased likelihood of students completing the course. On the other hand, El-Zein [18] report that implementation of a partially-online teaching medium has reduced student failure rates, as well as improving student satisfaction with the course. Koenig [19] however, suggests both faculty and student satisfaction decreases in online learning compared with traditional classroom learning.

In a study by Ibrahim [20], 126 higher education institutions were investigated, and 30% of universities offering engineering degrees in the United States were reported to offer online degree programs. While some engineering programs reported having based their education entirely over the internet, others use online tools to facilitate learning in engineering courses with a partially-online/hybrid approach [5, 18, 21], and others have tested the use of virtual or remote labs for engineering courses [22–26]. A factor preventing further acceptance of online learning is the presumed difficulty involved with online lecturing of mathematics based courses, as compared with the nature of courses that may be found in other disciplines [27]. The novelty of the study comes from the fact that quantitative results presented in this study comparing different modes of teaching for the course under study, Engineering Statistics, are one of the first in the field of mathematics based engineering courses.

2.2 Program details

The Department of Engineering offers a Bachelor of Science (B.S.) degree in Engineering. All students enrolled in the program take certain common courses in their freshman and sophomore years, only after which they choose their area of concentration. The course under consideration, ENGR2080 Engineering Statistics, is a calculus based course that all undergraduate engineering students are required to take. Currently there are four areas of concentration offered within the program: biomedical engineering; industrial engineering; mechanical engineering; software engineering. Students need to obtain 126 credits to obtain a B.S. degree. The programs are accredited by the Engineering Accreditation Commission of ABET. In addition to the Engineering degree, there is also a more focused, ABET accredited, Manufacturing Engineering degree offered within the Department which also requires this course.

2.3 Course details

Owing to the number of students registered for the ENGR2080 Engineering Statistics course, it was necessary to divide the course into two sections. Section A proceeded with a traditional lecture style throughout the semester. There were 28 students who had registered for Section A at the beginning of the semester. Section B, on the other hand, was designed as a partially-online course. There were sixteen students who had registered for Section B at the beginning of the semester. Having two sections offered during the same semester, covering the same content but with different mediums of teaching enabled a more comprehensive comparison of student success by the two methods.

The students that were enrolled in the Engineering Statistics course during the Spring 2012 semester were at different levels of their B.S. degree, as well as with different areas of concentrations. Course content was chosen so as to be applicable to different fields of engineering and therefore arouse interest in students from different backgrounds and with different professional interests. Course content can be summarized with the following topics: concepts of central tendency, scatter, and shape; continuous and discrete random variables and distributions; systems of random variables; hypothesis tests. The overarching goal of the course was to demonstrate the theory and applications of engineering statistics through examples and applications from different fields of engineering.

There were two midterms and one final exam throughout the semester for both sections. Both midterm exams were given on the same day, one after the other. All exams were administered in-class, had the same questions, and time limitations. Student learning was supported by three homework sets, each due a week before the respective exam. Exams and homework were graded at the same time without making a distinction between students from different sections so as to minimize potential variations caused by grading at different times. Several points were assigned to attendance and participation in the course. Ten attendance checks were taken at random intervals for Section A over the semester, whereas four attendance checks were taken for Section B, one at every in-class session. Weighted average of grades were used to calculate student grades for the course, where each exam comprised 25% of the total grade, for a sum of 75% for two midterms and a final, homework 15%, and 10% was assigned for attendance and participation.

Section A, with its traditional lecture style, met twice a week for one hour fifteen minutes each. Section B had in-class lectures only four times throughout the semester: once on the first day of class to introduce changes induced by having the partially-online course, and once before each exam to review exam content and solve additional problems for topics where students had difficulty. All lectures for Section B were distributed online through the use of Blackboard software. The Blackboard software is an effective tool for instructors to distribute course information, course material, announcements, and assignments, as well as facilitate communication. Additionally, the discussion board feature of the software was used to encourage student participation and discussions.

Regarding lectures for section B, presentations with voice recording of the instructor accompanying each slide were prepared. Such a format provides more independence to students to advance at the pace they desire, and listen to the important concepts or problem solutions as many times as necessary. Lectures were divided into multiple smaller topics or individual modules. Each module was a standalone description of the concept together with example problems where applicable. Each module was 15–20 minutes in length, so as to maximize student interest towards the topic and sustain their concentration. Each in-class lecture was subdivided and covered in 2–3 modules, on average. Subdivision of topics in such a manner results in a purely condensed form of topics, highlighting only the important concepts. From an instructor point of view, the ability to record lectures beforehand together with such time limitations aid in eliminating discussions of secondary importance and guide discussions towards only what is needed to describe the topic.

3. Methods

The goal of the study was to identify whether there was a significant difference between the learning of students who had registered on the traditional in-class Engineering Statistics section, Section A, as compared with the partially-online section, Section B. Both sections covered exactly the same material over the course of a 15-week semester, the only difference being the lecturing medium.

The number of students registered to Sections A and B were different at the beginning of the semester. Furthermore, there were multiple students who withdrew from the course during the semester for both sections. Some withdrew before the first midterm, where others withdrew during the semester. Some of the identified factors that contributed to student withdrawal from the course are: anticipation of a failing grade; anticipation of a grade that is below their cumulative grade point average (CGPA), primarily for honors students; schedule conflicts for professional students; credit transfers from another institution; financial constraints. In total, there were four students who withdrew from Section A and three students who withdrew from Section B. These students were excluded during the calculations in this study.

Owing to administrative issues, it was not possible to announce that Section B implemented a partially-online lecturing medium. Students learned about this during their first week of class. Therefore, student assignments to sections were random. While students were given an option to switch between sections during the first two weeks, none of them did so. In order to compare student learning and performance in the two sections, it was deemed necessary to check the CGPA and degree credits completed for students registered in both sections. Owing to the inherent randomness of student section assignments, a significant difference in these two factors was not expected. Results of this analysis are presented in Figs. 1–3.

Statistical procedures were used in the study in order to fully address the goal of the study and provide quantitative evidence. A hypothesis test was conducted as part of the discussions to check whether there was a significant difference in the mean grades of students in the two sections. A two-sided t-test for two samples was used for this purpose.

4. Results

Students who withdrew from their courses during the semester were excluded in the analysis. Four out of twenty-eight students withdrew in Section A, and three out of sixteen students withdrew from Section B. Therefore, the analyses that follow are based on twenty-four students for Section A and thirteen students for Section B.

The students that were enrolled in both sections of the Engineering Statistics course during the Spring 2012 semester were at different levels of their degree, as well as having different areas of concentration. Figure 1 shows students' progress towards their degrees, based on course credits completed.

Naturally, there were slight variations in the CGPA among students enrolled on both sections of the Engineering Statistics course. Figure 2 demonstrates the CGPA variation among students in both sections, where 4.0 is the highest CGPA possible.

The distribution of total grades for each section is shown in Fig. 3. Results are presented in terms of relative frequency in order to take into account the different number of students in each section, and so that the results are comparable.

Fundamental statistical indicators for student performance are presented in Table 1 together with factors that could affect student success. Results presented under the student grades column is the mean grade of students for the

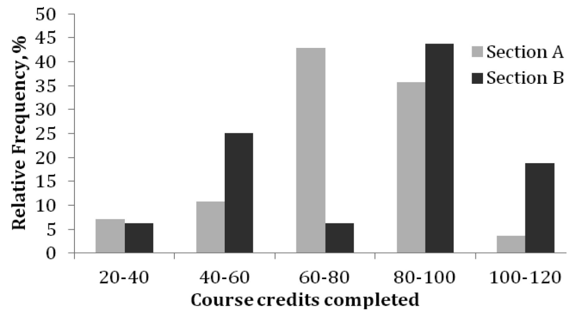

Fig. 1. Student progress based on course credits completed for degree.

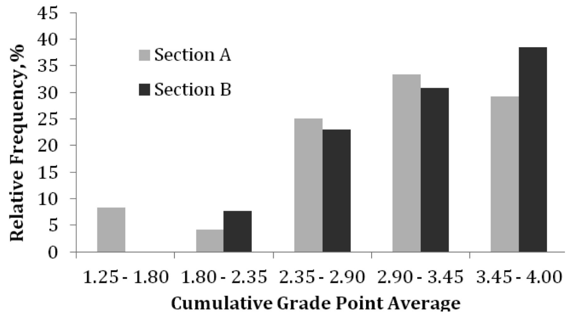

Fig. 2. CGPA of students enrolled to both sections of the Engineering Statistics course.

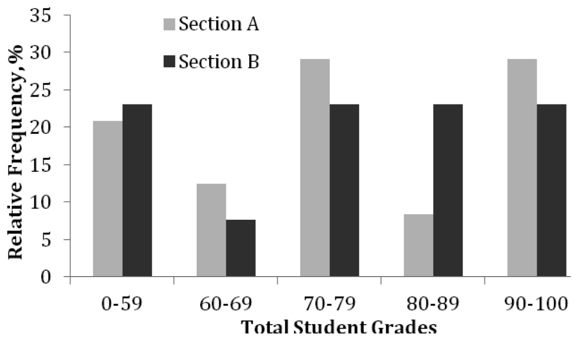

Fig. 3. Total grade distribution for both sections.

course accumulated over the entire semester over a scale of 100, and its standard deviation.

4.1 Hypothesis test

A two-sided t-test for two samples hypothesis test was carried out to check whether there was a significant difference between total student grades in the two sections. Values presented in Table 1 for total student grades were used in the analysis.

Table 1. Fundamental statistical indicators for student performance in both sections

		Student grades	Course credits completed	CGPA
Section A (n = 24)	Mean	68.3	79.2	3.09
	Standard deviation	20.5	17.1	0.70
Section B (n = 13)	Mean	68.6	80.5	3.11
	Standard deviation	26.8	23.3	0.67

Probability of type 1 error, α, was taken as 0.05. Steps of the analysis are presented below:

H_0: $\mu_1 = \mu_2$, H_1: $\mu_1 \neq \mu_2$

$$T = \frac{\bar{X}_1 - \bar{X}_2 - (\mu_1 - \mu_2)}{S_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \quad (1)$$

where $\bar{X}_1$ and $\bar{X}_2$ are sample means for Section A and B, respectively in Equation (1). n_1 and n_2 are sample sizes and are taken as 24 and 13 respectively. S_p is the pooled estimator calculated by Equation (2):

$$S_p^2 = \frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2} \quad (2)$$

where S_1 and S_2 are sample standard deviations for Sections A and B, respectively, taken from Table 1. By inputting the respective values into the equation, the following values are calculated:

$S_p^2 = 522.5$, $S_p = 22.9$ and $| t | = 0.032$.

From a two-sided t-table, P-value > 0.5 >> $\alpha = 0.05$. Therefore, the conclusion would be to not reject H_0.

5. Discussion of results

Although unrestricted student enrollment to Sections A and B provides a random sample for the study, it was still necessary to check previous student performance in both sections. While there are slight variations in course credits completed and CGPA of students enrolled in Sections A and B, mean and standard deviation results presented in Table 1 indicate that students in both sections were comparable in terms of degree progress, and academic success.

The mean grades of students in Sections A and B came out to be almost identical. However, the dispersion, or standard deviation of grades in Section B was somewhat higher than Section A. A larger sample size is necessary to investigate the implications of this outcome.

A hypothesis test conducted to check whether there was a significant difference between results of Section A and Section B indicate that there is not sufficient evidence to reject the null hypothesis, which was based on the two sections having equal mean grades. This result is in support of the previous conclusion from Table 1 that student learning in the two sections was comparable.

Based on these results, it can be concluded that students perform equally well in a partially-online course setting when compared with a traditional in-class lecture style. The course under analysis in the study was Engineering Statistics offered to undergraduate students, which is heavily based on mathematical calculations. Effective teaching of Engineering Statistics requires multiple numerical examples for each concept that is discussed. Results obtained in this study are in support of discussions that online teaching could also be a viable method to teach other problem-based engineering courses.

6. Conclusions

The effectiveness of partially-online teaching was investigated in this study by direct comparison between two sections of Engineering Statistics offered to undergraduate engineering students. Statistical analysis was carried out to provide formal evidence for claims in discussion. Course content, assignments, and student assessment were same for both sections. Section A had a traditional in-class lecture style, whereas a partially-online teaching method was implemented for Section B.

Although unrestricted student enrollment for these two sections provides a random sample, two important factors, course credits completed towards degree and current CGPA were analyzed. Results for these two factors were found to be similar which indicate a random sample where student progress and successes were comparable.

Total grades accumulated over the semester were analyzed to compare student performance in the two sections. Mean results were found to be almost identical, whereas the amount of variation in Section B was found to be slightly higher. Overall, taking student grades as an indication of their learning, it can be stated that transitioning from a traditional lecture style to a partially-online course did not adversely affect student learning for the course under mention.

The course under analysis in the study was Engineering Statistics offered to undergraduate students, which is heavily based on mathematical examples and calculations. Results obtained in this study are in support of discussions that partially-online teaching could also be a viable method to teach other mathematics based engineering courses.

Based on experience gained from the partially-online course, together with evidence found to support its implementation, a fully-online Engineering Statistics course was planned to be offered for Fall 2012, where there would be no in-class sessions.

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Can B. Aktaş is an Assistant Professor at the Mechanical, Civil, and Environmental Engineering Department at the University of New Haven. He received his B.S. and M.S. degrees from the Middle East Technical University, Turkey, and his Ph.D. from the University of Pittsburgh, USA. His areas of research include sustainable engineering, statistics and e-learning.

Yıldırım Omurtag is currently a Professor of Engineering and Science and was the Founding Dean of the School of Engineering, Mathematics and Science from 1999 to 2005 at Robert Morris University. Professor Omurtag, along with the team of faculty members he hired, established the School of Engineering, Mathematics and Science and obtained ABET accreditation for the B.S. degree programs in Engineering in record time. Prior to RMU he was at the University of Missouri-Rolla where he served as a Department Head and a Professor of Engineering Management in their School of Engineering.