COMPARISON OF ACADEMIC PERFORMANCE OF STUDENTS IN ONLINE VS TRADITIONAL ENGINEERING COURSE

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Abstract

Universities in the U.S. typically offer to teach introductory engineering courses in large classes to tackle the increase in undergraduate engineering enrolment and to save on cost of teaching. Previous studies done on traditionally taught large classes have shown the negative effects it has on students and faculty. Many institutions use online courses to teach these large classes due to the flexibility they provide students with in their schedule and pace of learning, as well as being less expensive for the university. This study aimed to investigate the effect of online pedagogy on the academic performance of students enrolled in mechanics of materials course taught at a U.S. Midwestern University. The findings of the study reveal that the online pedagogy had a negative effect on student academic performance when compared with the traditionally taught group. This was true for all demographics (gender, enrolment status, nationality) and categories (high, medium and low academic performance) of students except for high performing students for whom online pedagogy shows promise.

Abstract in Hindi

अमेरिका में विश्वविद्यालय आमतौर पर स्नातक इंजीनियरिंग नामांकन में वृद्धि से निपटने के लिए और शिक्षण की लागत को बचाने के लिए बड़ी कक्षाओं में परिचयात्मक इंजीनियरिंग पाठ्यक्रम पढ़ाते हैं। परंपरागत रूप से सिखाई गई बड़ी कक्षाओं में किए गए पिछले अध्ययनों ने छात्रों और शिक्षकों पर इसके नकारात्मक प्रभावों को दिखाया है। वेब प्रौद्योगिकियों के आगमन के साथ, ऑनलाइन पाठ्यक्रम लचीलेपन के कारण शिक्षा में ट्रेंड कर रहे हैं, जो छात्रों को उनकी अनुसूची और सीखने की गति प्रदान करते हैं, साथ ही विश्वविद्यालय के लिए कम खर्चीली भी हैं। इस अध्ययन का उद्देश्य यू.एस .मध्यपश्चिमी विश्वविद्यालय में पढ़ाए जाने वाले सामग्री पाठ्यक्रम के मैकेनिक्स में नामांकित छात्रों के शैक्षणिक प्रदर्शन पर ऑनलाइन शिक्षण के प्रभाव की जांच करना था। अध्ययन के निष्कर्षों से पता चलता है कि पारंपरिक शिक्षण समूह के साथ तुलना करने पर ऑनलाइन शिक्षण का छात्र शैक्षणिक प्रदर्शन पर नकारात्मक प्रभाव पड़ता है। यह उन सभी जनसांख्यिकी) लिंग, नामांकन स्थिति, राष्ट्रीयता (और श्रेणियों) उच्च, मध्यम और निम्न शैक्षणिक प्रदर्शन (के छात्रों के लिए सही था जो उच्च प्रदर्शन वाले छात्रों को छोड़कर जिनके लिए ऑनलाइन शिक्षाशास्त्र वादे को पूरा करता है।

Keywords: online, face-to-face, traditional, engineering education, student performance.

Introduction

Undergraduate engineering has seen a constant rise in enrolment since 2005 (Yoder, 2015). To handle the high enrolment of students, many universities have chosen to teach fundamental engineering courses in large classes. While this has the obvious advantage of cost reduction, large classes taught in the traditional manner have been shown to have a negative impact on student learning and dilute the learning process. Large classes refer to enrolment of 40 or more students in one class (Cuseo, 2007). Traditional class in this study refer to the class of students who are taught in a classroom setting with the instructor being physically present in the classroom following a fixed schedule of classes and exams. The traditional class in this study met three times a week for a full 50-minute lecture. Students could also meet the professor through an appointment or during their office hours for questions and doubts about the course. Students also had a choice of meeting with teaching assistants of the course regarding the same.

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While large classes offer the opportunity to teach students in student centred pedagogies like active learning and cooperative learning, the aim of this study is to see the effect of another emergent pedagogy, namely online learning. Online learning allows for seamless streaming of video lectures and providing students with online resources for the course content. The advantages of online courses include self-paced learning and flexibility of schedule that allows for working students to take such courses. These courses can also be attended from anywhere outside the traditional classroom. Online courses are offered at almost all universities and colleges where the credits acquired from these courses are counted towards a student's graduation.

Online classes in this study refers to the availability of web lecture videos, notes and materials over the internet required for the course. Two types of online videos were shared with the students: lectures and example problems. Lecture videos, on average, are 12 minutes long and they introduce new concepts. The example problem videos are about 10 minutes long and contain instructor-solved sample problems. Students had to submit weekly assignments based on the modules provided by the instructor and had scheduled proctored exams. Students of the online class could contact the professor via email regarding doubts and question regarding the course content or could set up a virtual meeting at an assigned time.

Mechanics of materials (MM), which is an introductory and a fundamental course required for many engineering disciplines, was examined to see the impact of online education on undergraduate engineering students. In the summer semester of 2016 two classes of the MM course were offered at the University; an online and a traditional class. The academic performance of students in the two classes were compared to see the effect of online education. Academic performance (AP) in this study refers to the final grades they received in their course. The academic performance in later courses, such as Mechanics of Materials, can be directly correlated to the student's performance in Statics of Engineering (Eisenberg, Beer, & Johnston, 2009; Benson et al., 2010; Rutz et al., 2003; Orr et al., 2008). The students' initial academic standing prior to starting the MM course was assessed from their scores in Statics of Engineering (SE). The final grades of SE were used as a predictor of the students' academic performance because it is a prerequisite course for the subsequent MM course. In addition to examining the impact of online learning on students, the impact on specific groups of students based on demographic characteristics and academic performance were also analysed.

Significance of the study

In a broad sense, this study will be a part in improving engineering education. It will provide insights to better understand online engineering education being provided to students. With the increasing popularity of online courses, it is necessary to evaluate the quality of education they provide to the students and a constant effort to improve these online courses has become important. This study will be one of the first to show the effect of online learning on large undergraduate engineering courses such as Mechanics of Materials. It aims to fill the knowledge gap in engineering students' performance in online classes especially for courses having high enrolment and required for many engineering majors.

Research questions

This study is designed to explore relationships between student characteristics and final grades obtained by the student to see which category of students is affected most by the online pedagogy. It also compares the grades of students enrolled in online and traditionally taught MM course to see which pedagogy achieved better academic performance.

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The study is designed to explore the following research questions:

1. How do engineering students' grades compare between students enrolled in an online mechanics of materials course and students enrolled in the traditional lecture format course?
2. How do the different group (demographics and academic performance) grades compare between students enrolled in an online Mechanics of Materials course and students enrolled in the traditional lecture format course?

Literature Review

Increase in engineering enrolment and large classes

Undergraduate engineering enrolment in the U.S. has seen an increase of 7.5 percent for the year of 2014. Enrolment for foreign students in undergraduate engineering has increased 9.8 percent. This trend has continued since 2005 (Yoder, 2015). Even with the increase in enrolment of domestic and international students, colleges and university professors still use the traditional instructor centred lecture format with hundreds of students enrolled in a class (Hejmadi, 2007) despite its ineffectiveness when teaching engineering students. Universities still allow for such large classes because of the alluring advantage of reduced cost (Kryder, 2002; Mulryan-Kyne, 2010). "Large classes are very prevalent in many universities and are often gateway courses to students' major fields of study" (Stanley & Porter, 2002; p.27). Statics of engineering and mechanics of materials are such courses, which face the issues of large enrolment because students across many engineering disciplines are required to take these courses (Stanley & Porter, 2002).

Issues related to effective teaching in high enrolment traditionally taught classes

Students taught in instructor centred traditional lecture are those who rely primarily on verbal instruction and notes taught by the faculty. Students also rely heavily on memorization through repetition. The idea is that one can quickly recall the meaning of the text or notes the more one repeats it (Schneider & Renner, 1980). Students taught in this manner are usually told what they should know. The faculty explains the concepts during lessons and the students are then expected to complete assignments to practice the concept (Cooper & Robinson, 2000; Huba & Freed, 2000).

Course design and preparation play an important role in student learning (Zorn & Kumler, 2003). Students learn through what they experience and how they are taught the materials. If the course is not designed appropriately students may face difficulty with how the material is taught and may not follow the course work. This issue can become amplified in large classes due to high enrolment which could result in confusion for the students' due to the limited access to faculty and teaching assistants (Adrian, 2010).

The way in which the course material is presented to the students is an important aspect for student learning (Al Nashash & Gun, 2013). Effective course delivery is critical for student learning and large classes usually rely heavily on presentations or lectures for course delivery. Typically, in traditionally taught large classes, the faculty becomes responsible for the material and concepts taught. The eagerness with which the faculty deliver course content will influence students to work hard over the course term, engage course concepts, and ideas to boost their learning (Fata-Hartley, 2011; Kryder, 2002).

Student learning is also affected by the way the course is managed (Cakmark, 2009). Large courses cause delay in feedback to students regarding assignments and exams. Students report

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less course satisfaction and give lower overall ratings (evaluations) for course instruction delivered in large classes (Cuseo, 2007).

Impact of high enrolment on students and faculty

In the paper by Cuseo (2007), which reviewed 95 articles reporting research on the effect of large classes defines mid-size classes as 36-45 students above which the classes were considered as large. Cuseo (2007) concluded that large classes heavily rely on faculty and reduce students' level of active involvement in the learning process. They also depreciate the quality of interaction between faculty and students, and feedback to students. They are also responsible for limiting creative thinking in students inside the classroom, and the breadth and depth of course objectives, course assignments, and course-related learning outside the classroom. Cuseo (2007) also reported lower course satisfaction and overall ratings (evaluations) of the course by students in large classes.

Monks and Schmidt (2011) article concluded that large classes are troublesome for the faculty to teach, have a negative effect on academic performance of students, and cause poor student learning. They (Monks & Schmidt, 2011) correlated large classes with reduced effectiveness in invigorating students' interest and slower return of assignments.

Large classes pose a problem for the faculty in the sense that the they need to invest more time when compared to small classes (Cole & Spence, 2012; Lindenlaub, 1981; McKagan et al., 2007; Mora et al., 2012; Saunders & Gale, 2012). Large classes require a well-structured approach to manage the class and make it difficult for the faculty to hold the attention of students. The students feel they are physically distant from the faculty (McKagan et al., 2007; Mora et al., 2012). Due to the high faculty student ratio, large classes require several graduate teaching assistants to assist with the evaluation of exams and assignments. The faculty in addition to working with students must supervise these graduate assistants. Often these teaching assistants have very little experience in teaching and may not even be familiar with the content of the course. This causes an added burden on the instructor who must make sure that their teaching assistants are effective (Ghosh, 1999; Rieber, 2004; Sargent et al., 2009).

Where students are concerned, large classes make them feel incognito because of the low level of interaction between students and due to faculty rarely being able to spare time to any individual (Cole & Spence, 2012). Due to the large enrolment, students are forced to learn more independently. They rely on the lectures, their own abilities, and communication with teaching assistants and peers (McKagan et al., 2007).

A well-structured online course, which includes creative lecture videos and timely feedback, could overcome the challenges associated with large classes. Online classes with creative lectures could keep the students focus in the course. They could also improve interaction between faculty and students when compared to large traditionally taught courses. The faculty would save time by not having to physically lecture students in the classroom. This could also prove beneficial in the sense that it would be less burden on the faculty.

Online pedagogy in engineering education

The U.S. Department of Education reviewed research (Means et al., 2009) from 1996 to 2008 to compare the academic performance of students enrolled in online pedagogy with face-to-face pedagogy. The meta-analysis (Means et al., 2009) concluded with "Students in online conditions performed modestly better, on average, than those learning the same material through traditional face-to-face instruction," and "The effectiveness of online learning approaches appears quite broad across different content and learner types. Online learning appeared to be an effective

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option for both undergraduates and for graduate students and professionals in a wide range of academic and professional studies." The studies included in the meta-analysis were usually from medicine or health care background. Other subject areas included computer science, teacher education, mathematics, languages, social science and business. The lack of available studies that compare traditional engineering courses with online engineering courses also signifies the need for research in this area. The limitations of the study (U.S. Department of Education, 2009) were that it did not consider if students enrolled in online courses spent more time working on the course than their face-to-face counterparts do. The time spent on the course rather than the online delivery itself could be the cause of online learners performing better than traditional learners do. The online course although being flexible could have caused the students to invest more time in the course. The study also did not account for the differences in content and pedagogy. It is possible that the online students received more material than the traditional students, which could have helped the former to have performed better. The study (U.S. Department of Education, 2009) also did not account for how effectively students were taught. Students taught by "good" teachers would do well regardless of the course pedagogy. Online classes have shown promise in other fields of education but there is limited amount of research that have explored their effects in engineering education.

Engineering education requires special attention when offered in an online medium when compared to other fields of education. Engineers need a science and mathematics base, which are challenging to teach through an online medium because of the laboratory experience and equation manipulation (Bourne et al., 2005). The study (Bourne et al., 2005) was done in 2005 and makes a strong argument for the use of online instructional technologies to teach engineering courses with the improvements in technology. The study anticipated that if online engineering courses were to become popular, blended classes would become prevalent. It also predicted that the quality of online course would improve through interactive teaching mediums, constructivist methodologies, standardization and institute collaborations. The article (Bourne et al., 2005). encourages engineering colleges to explore new methodologies possible within the online medium best applicable to engineering education. It also pushes for further data collection and distribution of the success and failures of online courses over the coming decade.

Teaching a course without the physical presence of the faculty is only possible in the modern world. The availability of internet access and the increase in use of personal computers has made online education the largest portion of distance learning (Evans & Haase, 2001). Having evolved from distance learning, online classes have rapidly become a trend in the university classroom. While face-to-face pedagogy has many established methods for effective teaching, online pedagogy lacks a model to which faculty can follow to effectively teach through online mediums. A common mistake in providing online courses to students is merely translating the traditional courses (Shaw, 2001). The main issues with designing an online course do not lie with the current technologies available, but the assumptions and conceptions that underlie their use (Shaw, 2001). The effective methods possible with the use of these technologies are hampered by the limited perspective of online courses held by those who think only in terms of static online tutorials and online books (Kilby, 2001).

A review of literature (Tallent-Runnels et al., 2006) on online teaching and learning concluded that asynchronous communication or online courses which are not live streaming facilitated in-depth communication (no more than traditional classes), students preferred to study at their own pace and students with previous knowledge or training in computers reported more satisfaction with online courses. The study (Tallent-Runnels et al., 2006) suggests further research on online learning should be conducted to answer other research questions such as learner outcomes, learner characteristics, course environment, and institutional factors related to the delivery system to test learning theories and teaching models inherent in the course design.

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A study (Rutz et al., 2003) compared the academic performance of students enrolled in statics course taught in traditional course and various instructional technology enhanced course. Among the various technology enhanced courses was a streaming video course. The streaming video course corresponds to student being provided with online lectures and videos. The students of the streaming video course could meet with the course faculty during allotted teaching hours. The streaming video closely compares with the online course being used in this research with the exception that the online students in this study could only contact the professor through online mediums. One of the conclusions of the study was that the students enrolled in the streaming video course performed significantly higher than their traditionally taught counterparts. The limitation of this study is that it was conducted over a decade ago. Since then there have been technological advancements in online mediums and the way traditional classrooms are taught have also evolved.

A more recent study (Thomas et al., 2011) compared the academic performance of students enrolled in traditional mechanics of materials course with technology enhanced courses. These courses included a "video replace lecture" course which corresponds to asynchronous online course. Here again the key difference with this study was the students were allowed to meet with the course faculty during allotted teaching hours. When the final scores were compared the study found no differences between the academic performance of traditional and online students.

Studies comparing online learning and traditional learning regarding engineering courses such as mechanics of materials and statics of engineering are negligible if not absent. Previous studies also do not account for the academic performance or learner characteristics of students in online courses. The first research question compared the academics performance of students enrolled in online pedagogy with those enrolled in traditional pedagogy. The second research question used the same comparison but for different categories of students.

A key aspect of this study compared to previous studies about online engineering courses is that the students enrolled in the online course could only contact the faculty via online mediums such as email, forums and online video session at allotted times. This aspect of the study is very important because if a course must be truly online, it must offer all its aspects online, which includes interaction with the faculty.

Method

Participant characteristics and setting

The participants examined in the study were students enrolled for Mechanics of Materials course, offered in the Department of Aerospace Engineering at Iowa State University, in the summer semester of 2016. The MM course was offered as an online course for the first time in summer 2016. The students taking the course online were on campus as well as off-campus students. The online course was jointly offered with traditional mechanics of materials course. Both classes of the course were conducted over a 10-week period. The choice to enrol for the class was up to the student. The sample consisted of 80 students of which 42 students were enrolled for the online class and 38 were enrolled for the traditionally taught class. Demographic characteristics of the sample consisted of 10 (12.5%) females and 70 (87.5%) males; 26 internationals (32.5%) and 54 nationals (67.5%) students; 9 full-time (12.7%) and 71 part-time (87.3%) enrolled students. Students who had registered for six credits or more were considered full-time students.

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Research design

The first research question was designed to determine whether there is a difference between the academic performances of students in large MM course taught in traditional instructor-centred pedagogy and those taught in online pedagogy. It also looks at the online class in detail to find out which category of students based on their demographic characteristics and academic performance are most affected by the online pedagogy.

To establish students' previous academic standing their final grade in SE was used as a benchmark. SE is a prerequisite course, which all students must take before they can enrol for mechanics of materials. Many researchers (Eisenberg, Beer, & Johnston, 2009; Benson et al., 2010; Rutz et al., 2003; Orr et al., 2008) believe that a student's performance in SE is predictive of their performance in MM. All research participants in the study were taught SE in a traditional class. They were divided into groups according to their choice of pedagogy MM (online and traditional). Students enrolled for the specific pedagogy on their own accord. Since the course was offered in summer semester, students may have chosen the online class because it did not require them to be physically present for classes or tests. Whereas students who stayed on campus during the summer (such as international students) may have preferred the traditional class. The final grades students obtained in SE were compared to see if both classes of MM started at the same level of academic standing. Once this was established, the final grades obtained by students in MM from the two classes were compared to see if there was an impact of the online pedagogy on the students. It is important to note that the traditional class and the online class had different instructors and exams which could have caused biased results.

The second research question explored the effect of pedagogy on various categories of students. Students were divided into various categories depending on gender, nationality, enrolment status, and academic performance (AP) in Statics of Engineering. The students' academic standing was assessed using their final grades in SE. The grades obtained by students in the MM course were compared for the two classes (online and traditional) to see the effect of the pedagogy.

The independent variable used to explore this research questions is the type of pedagogy- traditional instructor-centred class versus the experimental online class. The dependent variable considered for this research question is the final class grade obtained by the students of the two classes. The control variables employed in this research were student final grade in SE, gender, enrolment status, and nationality of the student.

Data collection

A database of all the participants involved in the study was obtained from the Office of the Registrar at the University after the IRB approval. The database included student demographic characteristics such as gender, enrolment status and National / International student. The database also included GPA, scores obtained in statics of engineering and Mechanics of Materials grades.

Data analysis

This study employed independent sample t-tests to examine the differences in students between those enrolled in MM online class and traditional class. To examine the impact of online learning on various student categories independent sample t-test were employed. The significance levels for all analysis was set at $p < 0.05$. Quantitative data was analysed using R statistical software. To ensure confidentiality the quantitative dataset was built using student identifiers, which were removed prior to any data analysis. All results are presented in a manner such that no student could be identified.

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Results

Prior to performing any statistical data analysis, it was necessary to establish if the students' grade in SE can be correlated to their academic performance in MM. A simple linear regression model was used which included all participants from the study to see the relationship between the variables. Out of the 80 cases analysed in the study, ten cases had missing data on scores obtained in SE. These missing data were excluded from the data analysis. The data presented below is for the 70 complete cases.

Table 1: Descriptive Statistics and t-test results of all student grades in Statics of Engineering (pre-requisite course) by their choice of pedagogy in Mechanics of Materials to establish a baseline for the class (online and traditional), its demographics and Academic Performance (AP)

Group	Traditional			Online			t-test results		
	N	Mean	SE	N	Mean	SE	95% CI	t	Sig.
Pedagogy	34	2.59	0.17	36	2.45	0.13	(-0.28, 0.55)	0.64	
Demographics									
Males	32	2.57	0.98	30	2.47	0.81	(-0.35, 0.57)	0.46	
Females	2	2.84	1.18	6	2.39	0.57	(-0.98, 1.87)	0.77	
U.S.	18	2.52	0.92	32	2.44	0.80	(-0.42, 0.58)	0.33	
International	16	2.67	1.06	4	2.58	0.50	(0.26, 1.57)	0.15	*
Part-Time	28	3.22	0.66	34	2.43	0.79	(-0.43, 0.47)	0.09	
Full-Time	6	3.00	1.15	2	2.84	0.23	(-0.82, 1.60)	0.78	
Academic Performance									
High	14	3.52	0.45	14	3.17	0.31	(0.06, 0.66)	2.45	*
Medium	9	2.44	0.17	10	2.50	0.18	(-0.23, 0.11)	-0.71	
Low	11	1.52	0.59	12	1.58	0.51	(-0.54, 0.41)	-0.30	

Note: *p < 0.05, **p < 0.01, ***p < 0.001

Before using simple linear regression, the final grades obtained by students for SE and MM were converted into a 4-point GPA scale (A = 4.00, A- = 3.67, B+ = 3.33, B = 3.00, B- = 2.67, C+ = 2.33, C = 2.00, C- = 1.67, D+ = 1.33, D = 1.00, D- = 0.67, F = 0.00). To run the regression, the final grade score obtained by students for SE was used as the independent variable and the final grade score obtained by the students in MM was used as the dependent variable. To estimate the regression line the ordinary least square (OLS) method was used. OLS is the simplest estimator that minimizes the sum of squared residuals to fit the regression line.

The linear regression on the data explained 16% (R-squared = 0.16) of variance in the scores obtained by the students of MM. The results are statistically significant ($F(1, 68) = 13.13$, $p < 0.001$). There is a directly proportional relationship between the scores obtained by students in SE and scores obtained by students in MM (Covariance = 0.47) and is a moderate relationship (Correlation = 0.40).

SE academic performance was compared for the two classes using independent two-sample t-test (two-tailed) which assumed equal variance. The analysis shows no statistically significant difference (Table 1) between the grades of the two classes (online and traditional) for the SE course. The two groups started MM course effectively at the same academic level. Among the groups (demographics and academic performance), international and high academic performance (AP) groups enrolled in the online class had lower score than their traditional counterparts in SE (Table 1). These groups (international and high AP) of online students started the MM course at a lower academic standing than the corresponding traditional groups. All other groups started the MM course at the same academic standing than the corresponding traditional groups.

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Table 2: Descriptive Statistics and t-test results of all student grades in Mechanics of Materials by their choice of pedagogy Mechanics of Materials to establish a baseline for the class (online and traditional), its demographics and academic performance (AP

Group	Traditional			Online			t-test results		
	N	Mean	SE	N	Mean	SE	95% CI	t	Sig.
Pedagogy	34	2.96	0.22	36	2.00	0.20	(0.36, 1.55)	3.19	**
Demographics									
Males	32	2.96	1.29	30	2.04	1.27	(0.26, 1.57)	2.81	**
Females	2	2.84	1.65	6	1.78	0.94	(0.26, 1.57)	1.19	*
U.S.	18	3.17	1.02	32	2.00	1.22	(0.49, 1.85)	3.44	***
International	16	2.71	1.52	4	2.00	1.36	(-1.05, 2.46)	0.85	
Part-Time	28	2.45	0.99	34	1.98	1.23	(0.31, 1.61)	2.96	**
Full-Time	6	2.94	1.32	2	2.33	1.14	(-1.73, 3.07)	0.69	
Academic Performance									
High	14	3.45	0.86	14	2.88	0.99	(-0.15, 1.29)	1.63	
Medium	9	3.00	1.36	10	1.63	1.07	(0.19, 2.55)	2.45	*
Low	11	2.27	1.44	12	1.28	0.96	(-0.60, 2.05)	1.96	

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

MM academic performance was compared for the two classes using independent two-sample t-test (two-tailed) which assumed equal variance. The analysis shows a statistically significant difference (Table 2) between the grades of the two classes (online and traditional) for the MM course. The mean for the students enrolled in the online pedagogy (M = 2.00) is lower than that of the students enrolled in the traditional pedagogy (M = 2.96). International, full-time, high AP, and low AP groups enrolled in the online class had no difference in MM course scores than their traditional counterparts in MM (Table 2). All other groups academically performed lower in their MM course than the corresponding traditional groups.

Discussion

The scores obtained by students in Statics of Engineering predict the scores obtained by students in Mechanics of Materials. From just one predictor, faculty who teach MM course could make a quick judgement regarding the classes' academic standing. This would apply regardless of the type of pedagogy used to teach the course.

There was no difference between the academic standing of students who enrolled in the traditional class and online class. This was expected since both classes were taught SE in the traditional instructor centred pedagogy and implies that both classes started the MM course at the same academic standing. At the end of the semester, there was a difference between academic standing of students of the two classes. The traditional class had outperformed the online class suggesting that the online pedagogy had a negative effect on the students. This is contrary to what the study at the U.S. Department of Education (2009) had concluded regarding online pedagogy. Even the studies (Rutz et al., 2003; Thomas et al., 2011) which looked specifically at the specific engineering course did not report a negative impact concerning online pedagogy.

There was no difference between the academic standing of male and female groups of the two classes before starting the MM course. It should be noted that the inferences made for the female group is limited due to the sample size and must be made with caution. Both groups enrolled in the online class performed lower than their corresponding groups in the traditional class. The online pedagogy had a negative impact on both genders.

There was no difference between the academic standing of U.S. students of the two classes for the MM course. The online pedagogy had negative impact on U.S. students' academic

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performance in MM when compared to the traditional pedagogy. Online international students started the MM course at a lower academic standing than their counterparts in the traditional classes. There was no difference between the grades of the international groups of the two classes suggesting a positive influence of the online pedagogy on international students.

There was no difference between the of part-time and full-time groups of the two classes before starting MM. The online pedagogy negative impact on part-time students' academic performance in MM. There was no difference between the grades of the full-time groups of the two classes suggesting a positive influence of the online pedagogy on full-time enrolled students.

Online high AP group had lower academic standing than their corresponding traditional group prior to starting the MM course. There was no difference between the grades of the international groups of the two classes suggesting a positive influence of the online pedagogy on students who had scored high in SE. There was no difference between the medium and low AP groups before starting MM. The online pedagogy had a negative impact on medium and low AP groups academic performance in MM.

The discussion raises an interesting question regarding high-scoring students: How are these high-scoring students better equipped for online courses than their lower scoring counterparts? Intuitively it could be said that high scoring students have a better grasp of the subject. It could also be that high scoring students have better self-regulation, which helped them achieve a high score in SE also. Online course may have helped these students change their learning behaviour which lead them to perform better.

Conclusion

The participants who enrolled for the summer 2016 Mechanics of Materials course for either class started the course at the same academic standing. At the end of the MM course, the students enrolled in the online pedagogy scored significantly lower than that of their counterparts implying the negative impact of the online pedagogy on the academic performance of the class. Similar negative effects of the online pedagogy were seen in male, U.S. and part-time enrolled students. The other demographic groups (i.e. females, international and full-time students) have limited sample size and inferences for these groups should be used with caution. When the students were divided into groups according to their grades in SE, the online pedagogy had negative effects on all but those students who had high scores in SE.

Online course in engineering education shows potential to offer a more flexible, accessible education and even a less expensive degree program. To achieve an online course, which is comparable to the face-to-face courses in terms of providing quality-engineering education, it is essential that continuous efforts be made to improve online pedagogy through research. The findings of the study suggest that online pedagogy for MM did not provide a good enough transition for students who are accustomed to traditional teaching styles. To improve the online course innovative methods of teaching must be used which engage the students in the learning process and encourage teamwork

The study has contributed to engineering education in the sense that it gives insightful information regarding online learning and undergraduate engineering courses. It contributes to literature in the much-needed area of comparing online pedagogy and traditional pedagogy in fundamental undergraduate engineering course.

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Limitations and Future work

The study reported here is susceptible to the following limitations. First, since the course was offered during the summer semester, most participants were either working or on an internship. This could have hindered the students in being able to manage their time or devote enough time to the course. Second, the traditional class and the online class had different exams and could have caused biased results. Third, the sample size for some of the demographic groups (female students, international students enrolled in the online pedagogy, Full-time students enrolled in the online pedagogy) was limited. Fourth, the limited sample is from one university and its findings may not represent the demographic composition of the full population.

To make the comparison of traditional and online pedagogy, it is recommended that the assessment content be kept same for both classes. The sample size of the quantitative study should be increased by including more participants from future cohorts of the online course to confirm the findings of this study. In addition to these, for future work it is recommended that further research into innovative online pedagogical techniques such as game based, or simulation-based approaches be conducted.

A qualitative research study into student habits regarding completing the online course of students from the various demographic and academic groups is also vital. This could give detailed insights into the different way students study especially for high AP students, the only group that was unaffected if not positively affected by the online pedagogy. Both classes of the Mechanics of Materials course were taught by different instructors, which could account for the difference in the academic performance of students of the two classes. The study also does not account for impact of different instructors on the students for Statics of Engineering. To predict an accurate picture of the academic performance of students, future studies must consider the impact of different instructors. Further research into student faculty interaction and its effects on student performance and attitudes towards online courses should be explored. A preliminary version of this manuscript (Bir & Ahn, 2016) was presented at the annual conference of FIE conference held in 2016.

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