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Applicability of online education to large undergraduate engineering courses

Devayan Debashis Bir
Iowa State University

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Devayan Debashis Bir

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Program of Study Committee:
Benjamin Ahn, Major Professor
Christina Bloebaum
Joseph Schaefer

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ABSTRACT

With the increase in undergraduate engineering enrollment, many universities have chosen to teach introductory engineering courses such as Statics of Engineering and Mechanics of Materials in large classes due to budget limitations. With the overwhelming literature against traditionally taught large classes, this study aims to see the effects of the trending online pedagogy. Online courses are the latest trend in education due to the flexibility they provide to students in terms of schedule and pace of learning with the added advantage of being less expensive for the university over a period. In this research, the effects of online lectures on engineering students' course performances and students' attitudes towards online learning were examined.

Specifically, the academic performances of students enrolled in a traditionally taught, lecture format Mechanics of Materials course with the performance of students in an online Mechanics of Materials course in summer 2016 were compared. To see the effect of the two different teaching approaches across student types, students were categorized by gender, enrollment status, nationality, and by the grades students obtained for Statics, one of the prerequisite courses for Mechanics of Materials. Student attitudes towards the online course will help to keep the process of continuously improving the online course, specifically, to provide quality education through the online medium in terms of course content and delivery.

The findings of the study show that the online pedagogy negatively affects student academic performance when compared to the traditional face-to-face pedagogy across all categories, except for the high scoring students. Student attitudes reveal that while they enjoyed the flexibility schedule and control over their pace of studying, they faced issues with self-regulation and face-to-face interaction.

CHAPTER 1

INTRODUCTION

Undergraduate engineering has seen a constant rise in enrollment since 2005 (Yoder, 2015). To handle the high enrollment 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 enrollment of 40 or more students in one section (Cuseo, 2007). Traditional classes in this study refer to the section 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. A traditional class meets three times a week for a full 50-minute lecture. Students can also meet the professor through an appointment or during his/her office hours for questions and doubts about the course. Students also have a choice of meeting with teaching assistants of the course regarding the same.

While large classes offer the opportunity to teach students in student centered 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 has become the new trend in the education system today. The increase in popularity of online learning can be attributed to developments in internet access and speed which allow for streaming video lectures and providing the 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 refer to the availability of web lecture videos, notes and materials over the Internet required for the course. Two types of online videos are 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 they 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 section 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, 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 sections for Mechanics of Materials were offered at Iowa State University; an online section (EM324XE) and a traditional section (EM324). The academic performance of students in the two sections was compared to see the effect of online education. Academic performance in this study refers to the final grades they received in their courses. The students' initial academic performance before starting the mechanics course was assessed from their scores in Statics of Engineering (EM274). The final grades of Statics of Engineering were used as a predictor of the students' academic performance because it is a prerequisite course for the subsequent Mechanics of Materials. The academic performance in later courses, such as mechanics of materials, can be directly correlated to the student's performance in Statics of Engineering (Beer & Johnston, 2004; Benson et al., 2010; Rutz et al., 2003; Orr et al., 2008). 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 was also analyzed. Finally, student attitudes towards the online course was examined through an anonymous survey administered through Qualtrics at the end of the semester. The survey consisted of questions related to various aspects of the course and course content.

Purpose of the study

The policy-makers at the SRI International for the Policy and Program Studies Service of the U.S. Department of Education argued that online pedagogy should replace face-to-face learning due to the advances in technology, which has made conducting online classes ever so easy. Online classes also offer the opportunity of a less expensive degree program. Those who are against online courses think that they tarnish the credibility of education being provided to students. Due to this conflict, the key point is to find out the effectiveness of online courses and their applicability in engineering education (Means et al, 2009).

Though online classes are widely available to students, there is still little research that focuses on engineering students' performance and attitudes towards online courses. This is especially true for courses with high enrollment such as Statics, Mechanics of Materials and Dynamics.

This study is designed to explore relationships between student categories and final grades obtained by the student to see which category of student is affected most by the online pedagogy. It also compares the grades of students enrolled in online and traditionally taught Mechanics of Materials courses to see which pedagogy achieved better academic performance. Finally, it explores the attitudes of students enrolled in the online section towards various aspects of the course to see which features of the course they liked or disliked. According to student responses, modifications to improve the online course will be made for the next cohort.

This 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. *Which types of students, in terms of students' characteristics and academic performance, benefit most from taking an online Mechanics of Materials class?*
3. *What are students' attitudes towards learning the Mechanics of Materials online?*

Significance of the study

In a broad sense, this study will be a part in improving engineering education. Apart from this, it will also provide insights to better understand online engineering education being provided to students. Online engineering courses, which are required and count towards a student's graduation, are being offered at almost all U.S. universities. 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 classes such as Mechanics of Materials. It aims to fill the knowledge gap in engineering students' performance in online classes and engineering students' attitude towards online courses especially for courses having high enrollment and required for many engineering majors.

CHAPTER 2

LITERATURE REVIEW

Increase in engineering enrollment and large classes

Undergraduate engineering enrollment in the U.S. has seen an increase of 7.5 percent for the year of 2014. Enrollment for foreign students in undergraduate engineering has increased 9.8 percent. This trend has continued since 2005 (Yoder, 2015). Even with the increase in enrollment of domestic and international students, colleges and university professors still use the traditional instructor centered lecture format with hundreds of students enrolled in a class (Hejmadi, 2007) despite studies showing 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 enrollment because students across many engineering disciplines take these courses (Stanley & Porter, 2002).

Issues related to effective teaching in high enrollment traditionally taught classes

Students taught in instructor centered 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 students 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 enrollment 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 and engage course concepts and ideas to boost their learning (Fata, 2011; Kryder 2002). Classes with large enrollment have a negative impact on this aspect for student learning.

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

Traditional large classes heavily depend on graduate teaching assistants to teach small sections of the class. To effectively teach large classes, these teaching assistants need to be competently prepared and monitored (Ghosh, 1999; Rieber, 2004; Sargent et al, 2009). 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.

Impact of high enrollment on students and faculty

Courses with large enrollment refer to more than 40 students in a class (Cuseo, 2007). In the paper by Cuseo, 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 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 also reported lower course satisfaction and overall ratings (evaluations) of the course by students in large classes.

Monks et al. (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 correlated large classes with reduced effectiveness in invigorating students' interest and slower return of assignments.

Large classes pose a problem on the faculty in the sense that the faculty member needs to invest more time when compared to small classes (Cole & Spence, 2012; Lindlaub, 1981; McKagan et al., 2007; Mora et al., 2012; Saunders & Gale, 2012). Large classes require a well-structured approach to manage the class and they 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. These graduate assistants must be supervised by the faculty in addition to working with students.

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 enrollment, students are forced to learn more independently, they rely on the lectures, their own abilities, and communication with teaching assistants and peers more than the instructor (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 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 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 which compare traditional engineering courses with online engineering courses also signifies the need for research in this area. The limitations of this study 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 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). This study 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 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. 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).

For example, game based approach to teach an online engineering course has shown promise. The study (Coller & Scott, 2009) concluded that the video game based approach engaged the students in the course and produced deeper learning of the concepts when compared to a traditional course. Student perception of the importance of the course also increased. The game based course was rated as one of the most important courses while the same course taught traditional was rated as one of the least important courses by the students. The game based approach transformed the course from one focused on exams and grades to one which was more applicable in the real world. The study recommended that research into activities which have the same effect as the game based approach must be encouraged.

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 suggests that 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.

One 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 conclusion 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.

Online pedagogy has shown promise in teaching engineering courses with large enrollment such as Mechanics of Materials and Statics of Engineering. 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 of various categories (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. The third research question analyzed student attitudes towards various aspects of the course in an effort to continuously improve the course for future cohorts of students and provide quality education through online mediums.

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 has to be truly online it must offer all of its aspects online which include interaction with the faculty.

CHAPTER 3

METHOD

Participant characteristics and setting

The participants examined in the study were students enrolled for Mechanics of Materials course, offered in the Aerospace Engineering Department of Iowa State University (ISU), in the summer semester of 2016. The Mechanics of Materials course was offered as an online course for the first time in summer 2016 at ISU and was conducted over a 10-week period. 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 sections of the course were conducted over a 10-week period. The choice to enroll for the section was up to the student. The sample consisted of 78 students of which 40 students were enrolled for the online section and 38 were enrolled for the traditionally taught section. 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.

Research design

The first research question was designed to determine whether if there is a difference between the academic performances of students in large Mechanics of Materials classes taught in traditional instructor-centered 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 and which category of students prefer to take the online class.

To establish students' previous academic standing their final grade in Statics of Engineering was used as a benchmark. Statics of Engineering is a prerequisite course, which all students must take before they can enroll for Mechanics of Materials. Many researchers believe that a student's performance in Statics of Engineering is predictive of their performance in Mechanics of Materials. All research participants in the study were taught Statics of Engineering in a traditional class. They were divided into groups according to their choice of pedagogy for Mechanics of Materials. The final grades students obtained in EM274 were compared to see if both sections of Mechanics of Materials started at the same level of academic performance. Once this was established, the final grades obtained by students in Mechanics of Materials from the two sections were compared to see if there was an impact of the online pedagogy.

The second research question explored the effect of pedagogy on various categories of students. Students were divided into various categories depending on gender, nationality, enrollment status and academic performance in Statics of Engineering. The students' academic standing was assessed using their final grades in Statics of Engineering. The grades obtained by students in Mechanics of Materials was compared according their section to see the effect of the pedagogy.

The third research question explored student attitudes towards the online course by administering an anonymous survey through Qualtrics. The survey was administered in the last week of the summer 2016 semester. To improve the reliability of the survey each question on the survey was scrutinized by two Qualitative analysis experts for biases in the question. Once the biases had been removed from each question, consents from the participants of the study were obtained. Each student enrolled for the course was sent a consent letter, a week before the survey was administered, which described the study and the motivation behind it. The letter also stated that the responses from the survey were anonymous so that the participants could answer the survey questions freely and to the best of their knowledge.

Independent variable

The independent variable used to explore this research question is the type of pedagogy-traditional instructor-centered class versus the experimental online class.

Dependent variable

The dependent variable considered for this research question is the final class grade obtained by the students of the two sections

Control variables

The control variables employed in this research were student final grade in statics of engineering, gender, enrollment status and nationality of the student.

Data collection

Quantitative database

A database of all the participants involved in the study was obtained from the Office of the Registrar at ISU. The database included student demographic characteristics such as gender, enrollment status, National / International student and majors. The database also included GPA, scores obtained in Statics of Engineering and Mechanics of Materials grades.

Qualitative database

An anonymous survey was administered to all students of the online section that asked demographic questions such as enrollment status (part-time/full-time), gender, major, ethnic background, and nationality (U.S. citizen/International). The survey additionally asked Likert type questions about course content such as appropriate length, quantity, quality, and if it supported students' learning. and open-ended questions regarding the course. This survey was administered to the students at the end of the semester. Responses for each open-ended question were analyzed for common patterns and trends, which were then arranged into theme categories. In order to incentivize the students Amazon gift cards worth $10 were given to all students who completed the survey. They were also awarded 5 points on their final scores of mechanics of materials. The survey had a response rate of 88% (35 out of 40 students).

The survey included the following open-ended questions which were analyzed for student attitudes:

- Describe course activities that are most helpful to your learning in this course
- Describe course activities that are least helpful to your learning in this course
- What do you like about the course?
- What did you dislike about the course?
- List the advantages of the online course as compared to traditional courses.
- List the disadvantages of the online course as compared to traditional courses.

Data analysis

This study employed independent sample t-tests to examine the differences in students between those enrolled in Mechanics of Materials online section (EM 324XE) and traditional section (EM 324). To examine the impact of online learning on various student categories independent sample t-test were employed. Quantitative data was analyzed using R statistical software. To ensure confidentiality the quantitative dataset was built using student identifiers which was removed prior to any data analysis. All results are presented in a manner such that no student could be identified.

The investigators of the study analyzed qualitative data obtained from the anonymous survey through pattern identification (Hays & Singh, 2012). Each open-ended question on the survey was analyzed for common patterns and trends. The common patterns and trends that emerged in the response were then made into theme categories. Each response to an open-ended question was put into one of these themes. A codebook (refer to Table 14) was made that listed all the themes generated in the survey analysis. The distribution of the responses for each question showed the students attitudes towards the course aspect or course content.

CHAPTER 4

RESULTS

Prior to performing any statistical data analysis, it was necessary to establish if the students' grade in EM 274 (Statics) can be correlated to their academic performance in EM 324 (Mechanics). A simple linear regression model was used which included all participants from the study to see the relationship between the variables. Out of the 78 cases analyzed in the study, 8 cases had missing data on scores obtained in EM 274. These missing data was excluded from the data analysis. The data presented below is for the 70 complete cases.

Before using simple linear regression, the final grades obtained by students for statics of engineering and mechanics of material was converted into a 4-point GPA scale. The GPA scale was obtained from Iowa State University and is listed below:

Table 1. Letter grade GPA scale

Letter Grade	GPA
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 Statics of Engineering was used as the independent variable (x) and the final grade score obtained by the students in Mechanics of Materials was used as the dependent variable. To estimate the regression line the ordinary least square (OLS) method was used. OLS is the simplest estimator which minimizes the sum of squared residuals to fit the regression line.

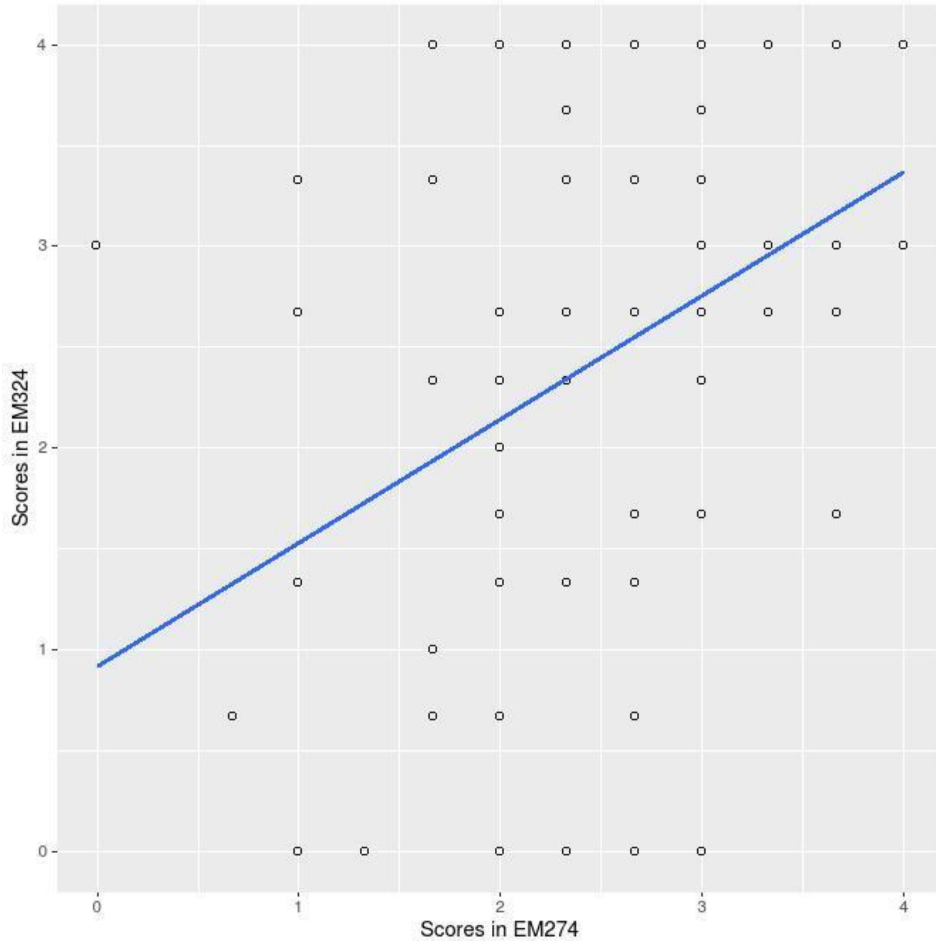

Fig 1. Relationship between scores obtained by students in EM274 and EM324

The results of the simple regression are summarized below:

Table 2. Regression summary of relationship between scores obtained by students in EM274 and EM324

Coefficients	Estimate	Std. Error	T value	Pr (<|t|)
Intercept	0.9180	0.4507	2.037	0.045
Score.274	0.6130	0.1692	3.623	0.001

Residual standard error = 1.224 on 68 degrees of freedom

Multiple r-squared = 0.1618

Adjusted r-squared = 0.1495

F-statistic= 13.13 on 1 and 68 DF ***(Null Rejected)***

P-value = 0.000557 ***(Significant)***

*Covariance = 0.4651263 (****Directly Proportional relationship****)*

*Correlation = 0.4022302 (****Proportional and Moderate relationship****)*

The scores obtained by EM 274 explains 16 % of variance in the scores obtained by the students of EM 324. The results are statistically significant with F (1, 68) = 13.13, $p<0.001$. There is a directly proportional relationship between the scores obtained by students in EM 274 and scores obtained by students in EM324. This relation is a moderate relationship.

Research question 1

For the first research question, the two groups, namely the traditional and the online section were compared. Each students' EM274 and EM324 grade was converted to a 4-point GPA scale. The GPA scale was obtained from Iowa State University. The prerequisite course EM274 was conducted in a traditional manner for all students. The research participants were then divided in to the two groups, traditional and online from their selection of pedagogy in EM324.

The mean, standard deviation and standard error of each group for EM274 are summarized below:

Table 3. Descriptive Statistics of EM274 course by pedagogy

	Class type	N	Mean	SD	SE
Final class grade EM274	Traditional	34	2.589	0.975	0.167
	Online	36	2.454	0.769	0.128

Prerequisite course (EM274) academic performance was compared for the two groups using independent two sample t-test (two-tailed) which assumed equal variance. The analysis shows no statistically significant difference between the two groups. The results show that the two groups started EM324 course effectively at the same level.

T-test results for comparison between participants for EM324:

t =0.644, df =68, p-value =0.522, 95% CI = [-0.283, 0.552]

The mean, standard deviation and standard error of each group for EM324 is summarized below:

Table 4. Descriptive Statistics of EM324 course by pedagogy

	Class type	**N**	**Mean**	**SD**	**SE**
Final class grade EM324	Traditional	34	2.952	1.279	0.219
	Online	36	2.000	1.216	0.203

An independent two sample test (two-tailed) which assumed equal variance was conducted to determine if there was a difference between the academic performance of the students enrolled in the traditional pedagogy and those enrolled in the online pedagogy.

The analysis shows a statistically significant difference between the two groups. From Table 4, the mean for the students enrolled in the traditional pedagogy (M=2.952) is higher than that of the students enrolled in the online pedagogy (M=2.000).

T-test results for comparison between participants for EM324:

t =3.191, df =68, p-value =0.002, 95% CI = [0.356, 1.547]

Effect Size

The effect size was calculated using Cohen's d.

Effect size = -0.763 (Medium to large effect size)

The results suggest that the online pedagogy had a negative effect on student academic performance.

Research question 2

For this research question the students were divided into the categories depending on their demographic characteristics. Their academic performances in EM274 were compared to see if there was any difference in the students before they started EM324.

Males and Females:

Table 5. Descriptive Statistics of EM274 course by pedagogy and gender

Group EM274	Traditional			Online		
	N	Mean	SD	N	Mean	SD
Males	32	2.573	0.981	30	2.467	0.810
Females	2	2.835	1.18	6	2.390	0.574

T-test results for comparison between Male participants for EM274:

t =0.464, df =60, p-value =0.644, 95% CI = [-0.352, 0.565]

The analysis shows no statistically significant difference between the Males in the two sections. The results show that the two groups started EM324 course effectively at the same level.

T-test results for comparison between Female participants for EM274:

t =0.766, df =6, p-value =0.473, 95% CI = [-0.977, 1.867]

The analysis shows no statistically significant difference between the females in the two sections. The results show that the two groups started EM324 course effectively at the same level.

Table 6. Descriptive Statistics of EM324 course by pedagogy and gender

Group EM324	Traditional			Online		
	N	Mean	SD	N	Mean	SD
Males	32	2.959	1.286	30	2.044	1.273
Females	2	2.835	1.648	6	1.778	0.935

T-test results for comparison between Male participants for EM324:

t =2.812, df =60, p-value =0.007, 95% CI = [0.264, 1.565]

The analysis shows a statistically significant difference between the Male groups. From Table 6, the mean for the male students enrolled in the traditional pedagogy (M=2.959) is higher than that of the male students enrolled in the online pedagogy (M=2.044).

T-test results for comparison between Female participants for EM324:

t =1.19, df =6, p-value =0.279, 95% CI = [0.264, 1.565]

The analysis shows no statistically significant difference between the female groups. From Table 6, the mean for the female students enrolled in the traditional pedagogy (M=2.835) is higher than that of the female students enrolled in the online pedagogy (M=1.778).

Effect Size:

The effect size was calculated using Cohen's d.

Effect size for Males = -0.715 (Medium effect size)

Effect size for Females = -0.973 (Large effect size)

The results suggest that the online pedagogy had a negative effect on student academic performance of both genders. The negative impact of the online pedagogy was more on Males because the results for females were not statistical significant.

Nationality:

Table 7. Descriptive Statistics of EM274 course by pedagogy and nationality

Group EM274	Traditional			Online		
	N	Mean	SD	N	Mean	SD
U.S.	18	2.519	0.920	32	2.438	0.800
International	16	2.667	1.062	4	2.583	0.501

T-test results for comparison between U.S. participants for EM274:

t =0.326, df =48, p-value =0.746, 95% CI = [-0.418, 0.581]

The analysis shows no statistically significant difference between the U.S. students in the two sections. The results show that the two groups started EM324 course effectively at the same level.

T-test results for comparison between International participants for EM274:

t =0.152, df =18, p-value =0.881, 95% CI = [0.264, 1.565]

The analysis shows no statistically significant difference between the International students in the 2 sections. The results show that the two groups started EM324 course effectively at the same level.

Table 8. Descriptive Statistics of EM324 course by pedagogy and nationality

Group EM324	**Traditional**			**Online**		
	N	**Mean**	**SD**	**N**	**Mean**	**SD**
U.S.	18	3.168	1.016	32	2.000	1.221
International	16	2.709	1.520	4	2.000	1.361

T-test results for comparison between U.S. participants for EM324:

t =3.438, df =48, p-value =0.001, 95% CI = [0.485, 1.851]

The analysis shows a statistically significant difference between the U.S. students groups. From Table 8, the mean for the U.S. students enrolled in the traditional pedagogy (M=3.168) is higher than that of the U.S. students enrolled in the online pedagogy (M=2.000).

T-test results for comparison between International participants for EM324:

t =0.848, df =18, p-value =0.401, 95% CI = [-1.046, 2.464]

The analysis shows no statistically significant difference between the International students groups. From Table 8, the mean for the International students enrolled in the traditional pedagogy (M=2.709) is higher than that of the International students enrolled in the online pedagogy (M=2.000).

Effect Size:

The effect size was calculated using Cohen's d.

Effect size for U.S. = -1.013 (Large effect size)

Effect size for International = -0.474 (Medium effect size)

The results suggest that the online pedagogy had a negative effect on student academic performance of both groups. The negative impact of the online pedagogy was more on U.S. because the results for International students were not statistical significant.

Enrollment Status:

Table 9. Descriptive Statistics of EM274 course by pedagogy and enrollment status

Group	Traditional			Online		
EM274	N	Mean	SD	N	Mean	SD
Part-Time	28	3.223	0.657	34	2.431	0.785
Full-Time	6	3.002	1.153	2	2.835	0.233

T-test results for comparison between Part-time participants for EM274:

t =0.094, df =60, p-value =0.926, 95% CI = [-0.429, 0.471]

The analysis shows no statistically significant difference between the Part-Time students in the two sections. The results show that the two groups started EM324 course effectively at the same level.

T-test results for comparison between Full-time participants for EM274:

t =0.784, df =6, p-value =0.463, 95% CI = [-0.824, 1.601]

The analysis shows no statistically significant difference between the Full-Time students in the two sections. The results show that the two groups started EM324 course effectively at the same level.

Table 10. Descriptive Statistics of EM324 course by pedagogy and enrollment status

Group EM324	Traditional			Online		
	N	**Mean**	**SD**	**N**	**Mean**	**SD**
Part-Time	28	2.453	0.986	34	1.981	1.225
Full-Time	6	2.941	1.324	2	2.330	1.141

T-test results for comparison between Part-time participants for EM324:

t =2.962, df =60, p-value =0.004, 95% CI = [0.312, 1.609]

The analysis shows a statistically significant difference between the Part-Time student groups. From Table 10, the mean for the Part-Time students enrolled in the traditional pedagogy (M=2.453) is higher than that of the Part-Time students enrolled in the online pedagogy (M=1.981).

T-test results for comparison between Full-time participants for EM324:

t =0.685, df =6, p-value =0.519, 95% CI = [-1.727, 3.070]

The analysis shows no statistically significant difference between the Full-Time student groups. From Table 10, the mean for the Full-Time students enrolled in the traditional pedagogy (M=2.941) is higher than that of the Full-Time students enrolled in the online pedagogy (M=2.330).

Effect Size:

The effect size was calculated using Cohen's d.

Effect size for Part-time = -0.420 (Small Effect size)

Effect size for Full-time = -0.472 (Medium Effect size)

The results suggest that the online pedagogy had a negative effect on student academic performance of both groups. The negative impact of pedagogy was more on Part-Time students because the results for Full-Time students were not statistical significant.

High, Medium, and Low Scoring Students:

Students were divided into three categories (high, medium and low) based on their academic performances in Statics of Engineering. The students who scored more than half a standard deviation above the mean (>2.955) were categorized as high-scoring category while the students who scored less than half a standard deviation below the mean (<2.083) were categorized as low-scoring. The students who scored in between (>=2.083 to <=2.955) were categorized as medium-scoring students.

Table 11. Descriptive Statistics of EM274 course

N	Mean	SD
70	2.52	0.871

Table 12. Descriptive Statistics of EM274 course by pedagogy and academic standing

Group	Traditional			Online		
EM274	N	Mean	SD	N	Mean	SD
High	14	3.524	0.448	14	3.166	0.314
Medium	9	2.443	0.170	10	2.500	0.179
Low	11	1.516	0.585	12	1.584	0.514

<u>T-test results for comparison between high-scoring participants for EM274:</u>

t=2.449, df =26, p-value=0.020, 95% CI= [0.057, 0.658]

The analysis shows a statistically significant difference between the High scoring students in the two sections. The results show that the High scoring group enrolled in the traditional pedagogy had higher academic performance than the High scoring group enrolled in the online pedagogy

<u>T-test results for comparison between medium-scoring participants for EM274:</u>

t=-0.705, df =17, p-value=0.490, 95% CI= [-0.226, 0.113]

The analysis shows no statistically significant difference between the Medium scoring students in the two sections. The results show that the two groups started EM324 course effectively at the same level.

T-test results for comparison between low-scoring participants for EM274:

t=-0.296, df =21, p-value=0.770, 95% CI= [-0.544, 0.409]

The analysis shows no statistically significant difference between the Low scoring students in the two sections. The results show that the two groups started EM324 course effectively at the same level.

Table 13. Descriptive Statistics of EM324 course by pedagogy and academic standing

Group	Traditional			Online		
EM324	N	Mean	SD	N	Mean	SD
High	14	3.454	0.862	14	2.881	0.992
Medium	9	3.001	1.364	10	1.633	1.070
Low	11	2.273	1.443	12	1.276	0.961

T-test results for comparison between high-scoring participants for EM324:

t=1.629, df =26, p-value=0.115, 95% CI= [-0.150, 1.294]

The analysis shows no statistically significant difference between the high-scoring student groups. From Table 13, the mean for the high-scoring students enrolled in the traditional pedagogy (M=3.454) is higher than that of the high-scoring students enrolled in the online pedagogy (M=2.881).

T-test results for comparison between medium-scoring participants for EM324:

t=2.445, df =17, p-value=0.025, 95% CI= [0.188, 2.548]

The analysis shows a statistically significant difference between the Medium scoring student groups. From Table 13, the mean for the medium-scoring students enrolled in the traditional pedagogy (M=3.001) is higher than that of the medium-scoring students enrolled in the online pedagogy (M=1.633).

T-test results for comparison between low-scoring participants for EM324:

t=1.963, df =21, p-value=0.06, 95% CI= [-0.60, 2.050]

The analysis shows no statistically significant difference between the low-scoring student groups. From Table 13, the mean for the low-scoring students enrolled in the traditional pedagogy (M=2.273) is higher than that of the low-scoring students enrolled in the online pedagogy (M=1.276).

Effect Size:

The effect size was calculated using Cohen's d.

Effect size for high-scoring = -0.617 (Medium Effect size)

Effect size for medium-scoring = -1.124 (Large Effect size)

Effect size for low-scoring= -0.821 (Large Effect size)

The results suggest that the online pedagogy had a negative effect on student academic performance of all the groups. The magnitude of effect size is largest for medium-scoring students and least for high-scoring students.

Research question 3

Table 14. Theme definitions and sample student quotes

Lecture Videos (LV) • Student responses about the lecture videos provided to them through the online module on Blackboard. *"The lectures are easily the most helpful. I read the book first, and sometimes try the homework before watching the videos.* *"Lecture videos are the least helpful for me because my learning style is more focused on working problems rather than being told how to solve a problem."*

Table 14 continued

Notes (N)

- Student responses that relate to the use of various materials provided through Blackboard. The materials include the e-book, slides and practice problems.
  "The least helpful activity is just viewing the slides without the video because the slides don't always show all of the written information."
  "The book readings are least helpful. I get a general understanding of the topic, but it isn't until the lecturers and example problems that the topic makes sense."

Example Videos (EV)

- Student responses about the example videos provided to them through the online module on blackboard. The example videos show the students how to solve a numerical problem systematically.
  "Example videos are very helpful, and the instructor's additional comments pertaining to various details…"
  "The example videos where problems are worked through seem to help me grasp concepts."

Homework (HW)

- Student responses about the weekly homework assigned to them.
  "The homework is the most helpful."

Exams and Tests (ET)

- Student responses about the exams and practice tests, which had to be taken to complete the course.
  "I would say the practice test give you the best idea of what to expect on the test."

None (NN)

- Student responses which stated "none".

Forums (F)

- Student responses to the use of discussion boards available on Blackboard.
  "There aren't a ton of components but sometimes the help forum doesn't work for me. It's harder to understand the questions and explanations without visuals."

Grading Scheme (GS)

- Student responses on the assigning of marks for exams and homework and how they were graded.
  "The class is almost all test grades. More of the class should be gauging how much work you put into it. Homework should be worth more than 10% for how much time it takes and how well it helps you understand the material."

Time-Management (TM)

- Student responses about managing their time to finish the course which included lecture videos, course materials, and homework.
  "It's easy to get behind on coursework. I also had very limited amount of time to study for exams or complete assignments because I was working full time."

Table 14 continued

Course Flexibility (CF) • Student responses about being able to take the course without being physically present in class by doing the online module and exams at a convenient time. *"Can do it on your own time so your work schedule is unaffected, don't have to worry about attending class, all materials are easily accessible."* *"Working according to your own schedule."*
Pace of Studying (PS) • Student responses about being able to go through the online module at their own speed so that they understand the concepts. *"Some advantages are that you can work on your own time to learn the material."*
Face-to-Face Interaction (FFI) • Student responses related to not being able to physically communicate with the faculty and other students. *"Cannot face-to-face ask questions instantly; limited source, no friends for face-to-face discussion."*

Q1: Describe the course activities that are most and least helpful to your learning in the course.

Table 15 shows the distribution of responses given by students for activities that were most and least helpful in their learning. For example, 12 students responded that homework was the activity most helpful to their learning. Out of those 12 students, three, one, five, and three students considered exams and tests, forums, lecture videos, and no aspect of the online course, respectively, to be least helpful to their learning.

Table 15. Cross tabulation of survey responses for the questions towards course activities

Activities most Helpful	Activities least Helpful						
	ET	**F**	**HW**	**LV**	**N**	**NN**	**Total**
ET	0	1	2	1	0	0	4
EV	0	0	0	3	1	1	5
HW	3	1	0	5	0	3	12
LV	2	2	6	0	2	1	13
N	0	0	1	0	0	0	1
Total	5	4	9	9	3	5	35

From the above table, we can see that lecture videos (n=13) and homework (n=12) were the activities most helpful to students. Somewhat ironically, lecture videos (n=9) and homework (n=9) were also the activities least helpful to students. This shows that students have a preference to learn from either one of these activities.

Students who considered lecture videos the most helpful activity to their learning said they liked the fact that they could pause the videos and take notes. A student responded, *"Learning the course from the video; video playback is the most helpful because I get to watch it repeatedly till I understand."* The negative aspects regarding the lecture videos were that they were too short (according to one of the students, *"The lectures are way too short and do not help at all learning. Feels like I am learning all by myself half of the time"*). An interesting finding here is that although students had mixed attitudes towards the lecture videos, they responded about the example videos (n=5) only with positive attitudes, primarily because they could understand how to solve problems through the steps shown in the example videos. A student responded, *"The example videos where problems are worked through seem to help me grasp concepts."* Students considered homework the most helpful activity to their learning primarily because it allowed them to practice numerical problems and prepared them for exams. A student responded, *"The homework and practice problems that are done during the lectures are the most helpful. I learn much better with examples."*

Q2: What do you like and dislike about the course?

Table 16 shows the distribution of responses given by students on the aspects of course that they liked or disliked. Apart from lecture videos (n=6) and notes (n=5), the course aspects liked by the students were course flexibility (n=16) and pace of studying (n=6). Both aspects are well known and intuitive advantages of taking online courses. For these students, the biggest advantage of taking the online course was course flexibility because they could dictate their own schedules.

A typical response was *"I like the freedom of the course to manage your time on your own rather than at specific times for lectures."*

Table 16. Cross tabulation of survey responses for the questions towards course aspects

Course likes	Course dislikes							
	ET	FFI	G	HW	LV	N	TM	Total
CF	4	1	1	3	1	1	5	16
EV	0	0	0	0	1	0	0	1
LV	2	0	1	2	0	0	1	6
N	0	0	0	2	1	0	2	5
NN	0	0	0	0	1	0	0	1
PS	2	1	1	1	1	0	0	6
Total	8	2	3	8	5	1	8	35

Students had negative attitudes towards the homework (n=8), the exams and tests (n=8), and their time-management (n=8) during the course. The students disliked the exams and tests primarily because while they could determine their own schedules with regard to the online modules, they had predetermined exam times to which they had to adhere. Another point to note here is that although students enjoyed the flexibility (n=16) the online course offered, five of these students were unable to manage their time to finish the course modules up to their own expectations. The course was designed in modules, intended to make the online learners more independent, yet a student disclosed, *"It is pretty easy to get behind on the coursework. I also had very limited time to study for exams or complete assignments because I was working full time."* This student's response supports previous findings that self-regulation is one of the most critical factors that influence the learning outcome of students in online courses (Steif & Dollar, 2009).

Q3: List the advantages and disadvantages of the online course as compared to traditional courses.

Table 17 shows the distribution of responses given by students on the advantages and disadvantages of the online course. For example, 20 students responded that the flexibility of the course to be one of the advantages of the online course, however, 14 of those students stated that they missed face-to-face interactions with faculty to be a disadvantage of the online course.

Table 17. Cross tabulation of survey responses for the questions towards course advantages and disadvantages

Course advantages	Course disadvantages			
	FFI	**N**	**TM**	**Total**
CF	14	2	4	20
NN	1	1	0	2
PS	11	1	1	13
Total	26	4	5	35

The biggest challenge faced by students in the online course was lack of face-to-face interaction (n=26). Students missed not being able to meet with other students and the professor, even though they could meet the professor virtually online. A student expressed, *"Cannot face-to-face ask questions instantly; limited source, no friends for face-to-face discussion."* Even though timely feedback was provided to the students, they still felt a lack of interaction. Again, the analysis showed that among the students who responded with course flexibility as an advantage, four of these students responded with time-management as a disadvantage. A response revealing the attitudes of these students was *"I'm more likely to wait till the last minute to do everything."*

The results imply that students felt strongly either positively or negatively about lecture videos, notes, homework, and exams and tests. These aspects of the course could be modified to help students learn better and become self-directed learners. Overwhelmingly, students missed face-to-face interaction with other students and the faculty. This aspect of the online course needs modification, possibly including teamwork exercises.

CHAPTER 5

DISCUSSIONS AND CONCLUCIONS

Discussion

1. The scores obtained by students in Statics of Engineering predicts 16 % of the variance in scores obtained by them in Mechanics of Materials. From just one predictor the faculty who teach Mechanics of Materials course could make a quick judgement regarding the classes' academic standing with respect to Mechanics of Materials. This would apply regardless of the type of pedagogy used to teach the course.
2. There was no statistically significant difference between the mean scores of Statics (EM 274) for students who enrolled in the traditional class (M= 2.589, SD= 0.975) and online class (M= 2.454, SD=0.769); *t =0.644, df =68, p-value =0.522, 95% CI = [-.283, 0.552]*. This was expected since both sections were taught Statics (EM 274) in the traditional instructor centered pedagogy and implies that both sections started the course at the same academic level. At the end of the semester, there was a statistically significant difference between the mean scores of Mechanics of Materials (EM 324) for students who enrolled in the traditional class (M=2.952, SD=1.279) and online class (M=2.000, SD=1.216); *t =3.191, df =68, p-value =0.002, 95% CI = [0.356, 1.547]*. This suggests that the online pedagogy had a medium-large negative effect (effect size = -0.763) on the academic performance of students as compared to the traditional pedagogy. This is contrary to what the study at the U.S. Department of Education had concluded regarding online pedagogy. Even the studies (Rutz et al, 2003; Thomas et al, 2011) which looked specifically at Statics of Engineering and Mechanics of Materials course did not report a negative impact concerning online pedagogy, if not a positive one.

3. There was no statistically significant difference between the academic performance of male and female students of the two sections of the pedagogy before starting EM324. The online pedagogy had a statistically significant negative impact on male students' academic performance in EM324 when compared to the traditional pedagogy with a medium effect size of -0.715. The online pedagogy did not have a statistically significant impact on female students' academic performance in EM324 when compared to the traditional pedagogy. The statistical significance for female students may not have been obtained because of the limited sample size (there were only 2 female students enrolled in the traditional section and 6 in the online section).
4. There was no statistically significant difference between the academic performance of U.S. and International students of the two sections of the pedagogy before starting EM324. The online pedagogy had a statistically significant negative impact on U.S. students' academic performance in EM324 when compared to the traditional pedagogy with a large effect size of -1.013. The online pedagogy did not have a statistically significant impact on International students' academic performance in EM324 when compared to the traditional pedagogy. The online pedagogy affected the U.S. students more than International students. The statistical significance for International students may not have been obtained because of the limited sample size (there were only 6 international in the online section).
5. There was no statistically significant difference between the academic performance of Part-Time and Full-Time students of the two sections of the pedagogy before starting EM324. The online pedagogy had a statistically significant negative impact on Part-Time students' academic performance in EM324 when compared to the traditional pedagogy with a small effect size of -0.420. The online pedagogy did not have a statistically significant impact on

Full-Time students' academic performance in EM324 when compared to the traditional pedagogy. The online pedagogy affected Full-Time students' more than Part-Time students. The statistical significance for Full-Time students may not have been obtained because of the limited sample size (there were only 2 Full-Time students enrolled in the traditional section and 6 students in the online section).

6. There was a statistically significant difference between high scoring students group for EM274. Students who enrolled for the online pedagogy had a lower academic performance than that of the students who enrolled for the traditional pedagogy. The online pedagogy did not have a statistically significant impact on high-scoring students' academic performance in EM324 when compared to the traditional pedagogy. There was no statistically significant difference between the medium and low scoring groups of both sections of the pedagogy for EM274. The online pedagogy had a statistically significant negative impact on medium-scoring students' academic performance in EM324 when compared to the traditional pedagogy with a large effect size of -1.124. The online pedagogy had a statistically significant negative impact on low-scoring students' academic performance in EM324 when compared to the traditional pedagogy with a large effect size of -0.821. It is important to note here that the high scoring students enrolled in the online pedagogy started the mechanics course at a statistically significant lower academic mean than their traditionally taught counterparts, but performed equally well. The maximum negative impact was observed in medium followed by low-scoring students. It 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 statics also.

7. Majority of the students in the online course showed a preference in the type of course materials they preferred which is either lecture videos or the homework. The advantage of the lecture videos was that the students could pause it to take notes or move at their own pace. Some students thought that the lecture videos provided were too short. Students liked the homework that was assigned because it prepared them for the exams. These two aspects and the notes provided of the course were the primary sources of study materials for the students. Example videos were another key aspect, which was appreciated by the students. They liked videos where they were shown systematically how to work through a numerical problem which helped them for their exams.
8. Students liked that the online course allowed them a flexible schedule. They also pointed out that the course allowed them control over the pace at which they completed the course materials. Both are well known advantages of online courses.
9. The interesting point to note is that none of the students found the discussion forum to be useful. Some students even responded with it being the least helpful. Teamwork and interaction are important aspects of effective learning. Forums are the only way online students can interact with each other. The online course must contain activities than require students to interact with each other such as group assignments. They could also be incentivized for using the discussion board. The faculty and the teaching assistants could also be involved in this to enhance the quality of discussion and steer the students in the right direction. To implement collaboration in the online course the following additions could be made:

- Discussion on weekly reports: A project report will be posted on the discussion forums for the students to read and discuss with other students to exchange ideas.
- Group projects: The class will be divided into groups of three. These groups will submit a short paper on a research idea and its applications from the concepts learned through the course.

For example, a weekly report will have students' complete simulation tutorials on cantilever beams with various types of loadings, such as uniformly distributed loads and point loads. These simulations can be performed using software like Solidworks, ANSYS or Abaqus. The tutorial will encompass all the basics (i.e. geometry creation, meshing, and solver selection) necessary to perform such simulations. Since the course is offered online, students have the choice of either downloading a student version of the simulation software or using the software available on campus via Virtual Desktop. Completing the tutorials will better equip student to understand how the deflections on beams occur due to applied loads. The students will get an opportunity to discuss the weekly reports with the TA and other students in the course over online course forums.

As for the group project, after the first half of the semester, the student groups, which will be predefined, will have to come up with demonstrations/experiments that apply some components of what was covered in the course for their final projects. These projects must demonstrate the group's learning of mechanics of materials concepts and their applications. The point of this exercise is to promote the effective use of forums and team collaboration in the course.

10. It is interesting to note that from the students who responded with course flexibility as the course aspect that they liked most, some from that pool responded with not being able to

manage their time. Cramming the weekly course content towards the submission date would diminish the quality of education being provided through the course. Students must be given a weekly mock schedule to adhere to so that they have an idea of the amount of time they need to spend on their homework and lecture videos. Students not being able to manage their time completing course modules and cramming assignments towards submission deadlines show that the students enrolled in the online course faced issues with self-regulation.

11. Two thirds of the class responded with missing Face-to-Face interaction with other students and faculty. This was the biggest disadvantage faced by the students enrolled in the online course. This could be eliminated using forums as discussed above. The unique Face-to-Face interaction with the faculty aspect of this course has affected the students and they felt it was a big disadvantage of the course.

Conclusion

The participants who enrolled for the summer 2016 Mechanics of Materials course for either section started the course at the same academic standing. At the end of the mechanics course the students enrolled in the online pedagogy scored significantly lower than that of their traditional counterparts implying the negative impact of the online pedagogy on the academic performance of the class as a whole. 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) did not show statistically significant difference due to limited sample size but the mean of these groups was lower than their traditionally taught counterparts. When the students were divided into groups according to their grades in statics, the online pedagogy had negative effects on all but the high scoring category of students. The qualitative analysis on the student surveys reveal that the students had a preference in their choice of study material i.e. lecture videos or homework Course Flexibility and Pace of studying themes were consistent as advantages of the online course among students. An important finding emerges when concerned with teamwork in online classes. Even though the students overwhelmingly missed the interaction with their fellow students, the limited mention of Forums in the survey (the only source of interaction between students) points to its limited use. The unique way the students interacted with the faculty had a negative impact on the student perceptions of their interaction with faculty. The interaction was not sufficient and students reported that the course lacked in this aspect.

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 Mechanics of Materials should only be offered to students who have high scores in Statics of Engineering. To improve the online course innovative methods of teaching must be used which engage the students in the learning process and encourage teamwork. Suggestions to improve the online course have been discussed in the previous section (refer point 9 in discussion section).

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. It is one of the few studies that provide useful insights into the relationship between learner characteristics (such as high, medium, and low scoring students) and online pedagogy.

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 section and the online section 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 sections. 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 simulations 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 scoring students who were the only group who were unaffected if not positively affected by the online pedagogy. Both sections 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 sections. 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. The study also throws light on the important aspect of interaction of students with their peers and faculty. Further research into student faculty interaction and its effects on student performance and attitudes towards online courses should be explored.

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APPENDIX IRB APPLICATION

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

Date: 7/12/2016

To: Devayan Bir
428 Stonehaven Drive Apt 5
Ames, IA 50010

CC: Dr. Benjamin Ahn
2324 Howe Hall
Shawn Dorius
308 East Hall

From: Office for Responsible Research

Title: Applicability of online classes to undergraduate engineering

IRB ID: 16-285

Study Review Date: 7/12/2016

The project referenced above has been declared exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b) because it meets the following federal requirements for exemption:

- (1) Research conducted in established or commonly accepted education settings involving normal education practices, such as:
  - Research on regular and special education instructional strategies; or
  - Research on the effectiveness of, or the comparison among, instructional techniques, curricula, or classroom management methods.

- (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey or interview procedures with adults or observation of public behavior where
  - Information obtained is recorded in such a manner that human subjects cannot be identified directly or through identifiers linked to the subjects; or
  - Any disclosure of the human subjects' responses outside the research could not reasonably place the subject at risk of criminal or civil liability or be damaging to their financial standing, employability, or reputation.

The determination of exemption means that:

- **You do not need to submit an application for annual continuing review.**

- **You must carry out the research as described in the IRB application.** Review by IRB staff is required prior to implementing modifications that may change the exempt status of the research. In general, review is required for any modifications to the research procedures (e.g., method of data collection, nature or scope of information to be collected, changes in confidentiality measures, etc.), modifications that result in the inclusion of participants from vulnerable populations, and/or any change that may increase the risk or discomfort to participants. Changes to key personnel must also be approved. The purpose of review is to determine if the project still meets the federal criteria for exemption.

  Non-exempt research is subject to many regulatory requirements that must be addressed prior to implementation of the study. Conducting non-exempt research without IRB review and approval may constitute non-compliance with federal regulations and/or academic misconduct according to ISU policy.

  Detailed information about requirements for submission of modifications can be found on the Exempt Study Modification Form. A Personnel Change Form may be submitted when the only modification involves *changes in study* staff. If it is determined that exemption is no longer warranted, then an Application for Approval of Research Involving *Humans Form* will need to be submitted and approved before proceeding with data collection.

Please note that you must submit all research involving human participants for review. **Only the IRB or designees may make the determination of exemption**, even if you conduct a study in the future that is exactly like this study.