Changing the Paradigm in Teaching Statics

Dr. Peggy C. Boylan-Ashraf
San Jose State University

Abstract

Introductory fundamental engineering mechanics (IFEM) courses, such as statics, mechanics of materials, dynamics, and fluids are based primarily on physics and mathematical concepts. In this paper, we suggest that new methodologies and active learning pedagogies, must be included in IFEM classrooms. This study focuses on a new paradigm in IFEM courses, identifying a new direction in engineering curriculum development— and emphasizes active rather than passive learning. Demographics of this study included 4,937 students, of whom 4,282 (86.7%) are males and 655 (13.3%) are females. The study was conducted over seven years, from 2006 to 2013. The undergraduate majors of the students included aerospace engineering, agricultural engineering, civil engineering, construction engineering, industrial engineering, materials engineering, and mechanical engineering.

Results of the study, obtained from an independent sample *t*-test, validated by using a non-parametric independent samples test and a general linear univariate model analysis, indicated that there is a difference between the teacher-centered pedagogy, with classes taught passively and the student-centered pedagogy, with classes taught actively.

The principal aim of this work is to propose a convincing argument using the data accumulated over seven years, that a new paradigm utilizing student-centered pedagogies in teaching IFEM courses should be emphasized over traditional, passive, teacher-centered pedagogies. After evaluating the effects of several variables on students' academic success, the results may provide important information for both faculty and researchers and present a convincing argument to those faculty interested in reform, but hesitant to abandon conventional teaching practices. By promoting student-centered, active learning strategies, the potential for improving understanding of engineering fundamentals on a larger scale may be realized.

Introduction

In this paper, a new paradigm of IFEM education is proposed. It is proposed that this new paradigm based on student-centered learning, rather than teacher centered learning can promote better understanding of fundamental knowledge concepts among students.

Student-centered learning (SCL) was first introduced in the 1960s under a reformed pedagogical model called guided inquiry [18]. SCL is usually introduced in 3 phases - an exploration phase, an invention phase, and an application phase. This pedagogical system has been found to be beneficial to students, providing them with better conceptual understanding compared to students who were taught using the more traditional methods or passive, teacher-centered pedagogies. [4,26,42].

Traditional-teacher centered learning (TCL) has methodologies that are based on verbal and printed words, rote memorization, and is also instruction driven [38]. Students who are taught with traditional instruction driven methods are given the concepts they should know and the lessons are presented in a deductive rather than an inductive manner [10,16], where the instructor conducts lessons by introducing and explaining concepts to students, and then expects students to complete certain tasks to apply these concepts that have been taught. This type of teaching method lacks individual thought or contribution and is based on rote learning. Modern student-centered learning types include project-based learning, case-based learning, and discovery learning, with 3 instructional approaches of active learning, cooperative learning, and problem-based learning [30].

This paper is based on a quantitative study, and is designed to explore variables related to academic success of students. It also investigates the most effective way to teach IFEM courses in large lectures, comparing *traditional pedagogy*, TCL, which is the full 50-minute lecture, three times a week to an *experimental (student-based) pedagogy*, SCL, which is the 50-minute, three times a week class centered not on instructions or lectures, but on active learning. IFEM courses generally include statics, mechanics, and dynamics, and these subjects are essential course components of engineering disciplines [40]. The variables used for this study are demographic characteristics of students and grades earned in class. This study was conducted using data over a period of seven years—from 2006 to 2013—in statics (EM 274) as taught at Iowa State University. Data has been collected from multiple instructors in the school, teaching multiple sections.

Statics is a fundamental discipline in engineering and was chosen because of its concepts and applications[6,33] that are so basic in engineering. It is a fundamental prerequisite for subsequent courses such as mechanics, dynamics, and tool design [5,28]. Many researchers [5,6,28,33] have argued that performance in courses such as dynamics and mechanics correlate to success or knowledge in statics.

In the past, statics has been taught in traditional lecture style classroom scenarios. According to research in human learning [43,46], humans think, learn, and solve problems by making connections and associations to previous experiences. Several researchers [13,43,46] have argued that if the fundamental concepts are learnt in a passive manner, through lecture or passive reading, the experience may not have the potential to build connections or bolster learning. Thus, the determining factors that could facilitate academic success in statics should be a major concern in engineering specifically, and in education generally, and can have an impact on curriculum development.

Literature Review

A. Introduction: Creating a Meaningful Curriculum in Introductory, Fundamental Engineering Courses

Since the early 1970s, the major emphasis on curriculum development in engineering education has been on the implementation process [9,31,44]. Even now engineering curriculum development continues to remain a challenge in education and possibly requires a collective effort to build a new and different form of teaching engineering classes, particularly IFEM courses. Research on engineering education has tried to emphasize teaching delivery [2,7,23,37] and a meaningful curriculum [1,9,35]. Policy makers, curriculum specialists, university educators, and parent groups, have all sought the perfect method to teach students. The emphasis has been on project-based learning, case-based learning, discovery learning, with three instructional approaches of active learning, cooperative learning, and problem-based learning [30].

Educational reformer John Dewey [11], suggested a profound curriculum change. Dewey believed that all genuine education comes from experience and identified two forms of education —traditional and progressive.

Dewey argued that every experience lives on or becomes embedded in future experiences and traditional education do not give genuine experiences, whereas progressive education insists upon the quality of the experiences. The type of curriculum Dewey recommended was not created by "experts" outside the classroom; but according to Dewey, must be created between the instructor and the students collaboratively, inside the classroom.

Emphasizing on Dewey's principles, several other scholars such as Alwerger and Flores [3] suggested that "learners (both instructor and students) should be at the center of learning, asking critical questions, engaging in meaningful problem-posing and problem-solving, and creating and recreating knowledge". Harste [15] stated that curriculum has a meaning-making potential where "knowledge is created, and recreated at the point of experience, and provides opportunities for both instructor and students to experience themselves as learners, engaged together in inquiry to create, critique, and transcend their present knowledge".

Many other scholars of engineering education [22,23, 29, 34], have built upon Dewey's theories and recommendations, and have emphasized on an active, cooperative, problem-based learning. Active, student centered learning or SCL, has been suggested as the new curriculum development methodology for introductory, fundamental engineering classes. The theme strongly suggests that instructor and students must collaborate to create new ways of learning and new modes of understanding [29]. In this new approach through SCL, learners would be able to make choices and form their own perspective on ideas that are important to them and possess freedom to think, observe, and ask questions [34]. This paper highlights the concept of "new learning" and investigates instructor and student collaboration in IFEM courses. In these courses, students and teachers participate in a curriculum that is generated by active and cooperative learning, as suggested by Dewey and other scholars. Using this study and the data, this paper investigates whether there is a stronger development of student conceptual learning in active learning than in passive learning.

B. Role of the Instructor in Developing a New Curriculum in Engineering Education

Different faculty members in engineering have different opinions on curriculum development. Some instructors take an authoritarian stance and provide students the traditional teacher-centered, lecture based education [38]. In the traditional education setting, students are presented concepts in lessons and learn through rote leaning or deductive reasoning [10,16]. Other instructors are less involved, take a laissez-faire approach and remain primarily an observer—as the instruction technique allows students to grow and learn on their own with little or no extrinsic intervention[25]. The third case scenario that is proposed in this paper is the active learning, student-centered collaboration model in which teacher and students can co-create the learning experience.

The role of the instructor in the engineering classroom cannot be separated from the theories of learning. To understand the complex process of learning, theories about human learning can be categorized into six broad paradigms - behaviorism, cognitivism, constructivism, experiential, humanistic, and social-situational learning theories [39]. Out of these six theories of learning, the constructivism theory of learning has often been used as a model to construct a theoretical perspective in engineering education [12,20,41,45]. Constructivism that largely aligns with engineering education is a theory of learning that proposes that a learner's knowledge comes from his/her already accumulated knowledge, like the purposeful, reflective, and methodical nature of engineering. There are several guiding principles of constructivism [14,20,24,36,41]:

1. Understanding comes from interactions with the environment and from the experiences related to accumulated knowledge. A learner's knowledge is derived from his/her pre-existing knowledge and experience; and new knowledge is formed when previous experiences connect to the new content.
2. Conflict or confusion in the mind is the stimulus for learning and determines the organization and nature of what is learned.
3. Knowledge involves social negotiation and evaluation of the viability of learning.

The literature suggests that a change in curriculum development in teaching IFEM courses may be necessary. When compared with implementation strategies of learning theories, the active learning model combined with the cooperative learning model, is in alignment with the constructivist view, and also provides a framework for fostering the development of student learning through collaboration and cooperation —this study explores the development of learning as it relates to methods of teaching in engineering education.

Research Questions

This study opens with two research questions:

1) What is the difference if any, between passive, teacher-centered instruction or traditional teaching procedures, and active, student-centered instruction and the collaborative learning model?
2) Do additional active, student-centered learning materials or teaching methodologies improve student performance

Methodology

A. Population

The population or subjects for this study was engineering students enrolled at Iowa State University. Located in Ames, Iowa, Iowa State University, ranks among the top twenty schools in the nation. Within the engineering division, bachelor's degrees are awarded in aerospace, chemical, civil, industrial and manufacturing, mechanical, and computer science engineering [17]. The population, from which the respondents were drawn, are undergraduate students enrolled in statics of engineering (EM 274) from Fall 2006 to Spring 2013. The sample consisted of a total of 4,937 students, of whom 4,282 (86.7%) are males and 655 (13.3%) are females. The students' majors included: aerospace engineering, 776 (15.7%); agricultural engineering, 208 (4.2%); civil engineering, 792 (16.0%); construction engineering, 492 (10.0%); industrial engineering, 372 (7.5%); materials engineering, 251 (5.1%); and mechanical engineering, 1,732 (35.1%) students. There were 314 students (6.4%) who were enrolled outside the majors mentioned above.

B. Design and Procedure

The typical lecture format is the traditional teacher centered learning or TCL, wherein the faculty member speaks, and the class sits facing the instructor. Interaction between the teacher and students often appear stiff and limited to questions and answers. From the observations it can be argued that the typical lecture format limited interactions among students and also created a rigid interaction pattern between teacher and students during classes.

Active learning, on the other hand, as implied by its very title, is something "other than" traditional lecture format. The concept of active learning in this study is simple: rather than the instructor presenting facts to the students, the students play an active role in learning by exploring issues and ideas, collaborating with each other, and learning through interaction under the guidance of the instructor. Instead of memorizing and internalizing a set of often loosely connected facts, the students learn a way of thinking, asking questions, searching for answers, and interpreting observations.

For this paper, a cross-sectional, ex-post facto study was carried out on two groups of participants over a period of seven years —from Fall 2006 to Spring 2013. The sample population consisted of 1) undergraduate students at Iowa State University who were enrolled in the traditional (passive learning) pedagogy statics (of engineering) classes from Fall 2006 to Spring 2013, and 2) undergraduate students at Iowa State University who were enrolled in the experimental (active learning) pedagogy statics (of engineering) classes from Fall 2006 to Spring 2013.

To maintain extraneous factors as constant, passive learning and active learning classes shared identical syllabus, grading schema, homework problems, and examination questions. This procedure was rigorously repeated each semester throughout the study from Fall 2006 to Spring 2013. Although homework and examination problems were graded by numerous teaching assistants each semester, a standard grading policy and outline were used to aid in uniformity and consistency in grading (minimizing variability in grading).

Independent Variable

The independent variable used in this study is the *type of class*—traditional, passive learning class versus experimental, active learning class.

Dependent Variable

The dependent variable used in this study is *final class grade*.

A student database was obtained from the Office of the Registrar at Iowa State University. One of the authors of this paper taught the experimental, student-centered pedagogy classes each semester from Fall 2006 to Spring 2013. Multiple members of the faculty from the aerospace engineering department at Iowa State University taught the traditional, teacher-centered pedagogy classes from Fall 2006 to Spring 2013. Data was tabulated for both these types of teaching procedures.

C. Data Analysis

This study used an independent samples *t*-test, a nonparametric independent samples test, and a general linear univariate model analysis to investigate the outcomes of student learning effectiveness, using two different approaches – traditional and experimental. The study is based on the impact of learning interventions using student-centered pedagogy on their academic achievement and progress.

The traditional (passive, teacher-centered pedagogy) classes involved 50-minute lectures with no interruptions, other than occasional questions from students. On the other hand, the experimental (active, student-centered pedagogy) classes involved interventions including supplemental videos and interactive-teaching style (active, student-centered learning pedagogy), using think-pair-share, one-minute points, peer teaching, and problem solving in groups [30]. Supplemental videos (as teaching or learning materials) were created by one of the authors of this paper using Corel Painter 12 and Camtasia. Each video is no longer than 8-10 minutes where it re-emphasizes important points of materials being discussed in class. The order of activities was changed from lecture to collaboration for the active learning classes such that students would enter the class with a sense of anticipation and engage in active participation. These activities are the conceptual backbone that shapes the new student-centered pedagogy, The constructivism theory of learning is used in the active, experimental classes. Constructivism strongly encourages instructors to be aware of their students' capacities or needs and agrees with Dewey [11] and numerous other scholars [22,23, 29, 34] that: 1) learning is social, 2) learners need choices to connect to personal experiences, and 3) learning is active and reflective.

Quantitative data collection was employed in this study, which allowed the data to be analyzed using statistical analysis procedures provided in SPSS statistical software. To ensure confidentiality, a dataset was built using student identification numbers; however, as soon as the dataset was completed, all student identifiers were removed prior to any statistical analysis and all results are presented in aggregate form such that no individuals can be identified. This process ensured that the researchers of this project cannot identify the individuals to whom the data pertain and that the entire dataset remains anonymous and confidential. An exempt classification for the human subjects research office was obtained from the Iowa State University Institutional Review Board.

In the initial part of the study in 2006, active learning involved collaboration between two or more students. In the latter part of the experiment, other procedures were used that involved peer teaching and larger group collaboration and interaction. Supplemental videos and learning materials were added in 2011, during the experimental process.

Results And Discussions

Before performing any formal statistical data analysis, a histogram of the dependent variable was examined to confirm normality. Normality assumptions were however, not met. The independent samples *t*-test was validated using a non-parametric independent samples test and using a general linear univariate model analysis.

Of the 4,937 cases analyzed in this study, 315 cases (6.38%) were missing data on pre-college performances. Missing data is a problem frequently encountered and occurs in all types of studies, no matter how strictly designed or how hard investigators try to prevent them [8,21,27,32]. When predictors and outcomes are measured only once (such as in this study), *multiple imputation of missing values* is the advocated approach [21,32]. In this study, most of the missing data (particularly high school grade point average, American College Testing scores and Scholastic Aptitude Test scores) were highly associated with international students; thus trimming the original data set was not an option, to avoid reducing the sample size in favor of U.S. students.

The multiple imputation approach executed in SPSS, conveniently ran simulations and searched for patterns in the available data set by creating a probability-based judgment as to what the missing data would likely be, so that this can be replaced to create a full data set. In this study, five imputations were used and they were performed in sequence. This study presents only results of the fifth imputation.

For the first research question, comparisons between the 2 groups (traditional versus experimental) were performed, which included: pre-college performances, descriptive statistics, and comparison of means to determine whether there is a difference between the 2 groups or between the results obtained from student-centered and teacher-centered learning. Each analysis is described below:

Pre-college performances were compared between the 2 groups and the analysis shows no statistically significant difference in means of pre-college variables, which included high school grade point average; American College Testing (ACT) subject scores in English, Mathematics, and the Composite ACT; Scholastic Aptitude Test (SAT) scores in Verbal and Mathematics subject scores. These results show that students in both groups essentially started at the same level when they entered college. A summary of descriptive statistics (N, mean, and standard deviation) of the dependent variable by class type is seen in Table 1. The table shows that the experimental class (active, student-centered learning pedagogy) has a higher mean score than that of the traditional class (passive, teacher-centered learning pedagogy), and the standard deviation of the experimental class is lower than that of the traditional class. The mean shown in the results summarized in Table 1 is out of a 4.00 scale.

An independent samples *t*-test determined if there was a difference in student performance in statics, as measured from class grades between students taught using the active, student-centered approach and the passive, teacher-centered approach over a period of seven years, 2006 to 2013.

The results showed that there was a statistically significant difference in final class grades between the experimental, active, student-centered class (M=3.09) and the traditional, passive, teacher-centered class (M=2.85); $t(4934.843)=7.987$, $p < .001$, and that the student-centered pedagogy does have a positive and significant pedagogical effect on students. The effect size for this difference was calculated as 0.226.

Due to violations of normality when examining the histogram of the dependent variable, the results of the independent samples *t*-test were validated using a nonparamet-

	class type	*N*	*M*	*SD*
final class grade	traditional	2449	2.71	1.15
	experimental	2488	3.11	1.00

Table 1. Descriptive Statistics of Independent Variable

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of **final class grade** is the same across categories of **type of class**.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.

Asymptotic signicances are displayed. The significance level is .05.

Figure 1. Results of nonparametric independent samples tests of the dependent variable.

ric independent samples test, as shown in Figure 1. Again results show that indeed there is a statistically significant difference in student performance as measured through final class grade.

A general linear univariate model analysis was used, and this again validated the results of the independent samples *t*-test and of the nonparametric independent samples tests that there was a statistically significant difference ($p < .001$) found between the traditional, active, student-centered class and the passive, teacher-centered class, as seen in the results summarized in Table 2—the tests of between-subjects effect of class type.

Finally, to answer the overarching second research question of this study—*do constructivist pedagogies using different levels of interventions improve student performance measured through comparisons of final course grades of different cohorts taught by a single faculty member?*—a general linear univariate model analysis was used to investigate the different comparisons of cohorts taught using the experimental, student-centered pedagogy, as seen in the results summarized in Table 3.

Also, a summary of results as seen in Table 4 shows that, in comparison to the cohort of 2013, there is a statistically significant difference in student performance each year throughout the study, except with cohorts in 2011 and 2012. There is no statistically significant difference between the 2013 cohort compared to the 2011 cohort and also between the 2013 cohort compared to the 2012 cohort. This might be due to the fact that supplemental videos were added as interventions of active learning in 2011; for the last three years of the research (2011, 2012, and 2013) all cohorts in the experimental, active, student-centered classes experienced full injections of interventions—which involved the full usage of active learning pedagogies of think-pair-share, one-minute muddiest point, peer teaching, and problem solving in groups, and supplemental videos. Thus, no statistically significant differences in student performance between the 2013 cohorts compared to the 2011 cohorts and also between the 2013 cohorts compared to the 2012 cohorts were expected. The summary of results in Table 5 confirmed this finding.

The first three years, beginning 2006, when active learning was just introduced, there was no statistically significant difference found between the 2 groups –in fact in 2006 students in the experimental class performed worse compared with traditional methods of teaching. However, as seen from this table, each year starting 2009 there was a statistically significant difference between the traditional class versus the experimental class. Cohen's d score ranged from 0.3 to 0.9. In 2013 students in the experimental class performed almost 1 standard deviation higher than the traditional class (Figure 2). This might be due to the fact that supplemental videos were added as interventions of active learning since 2011. For the students in the experimental class, there are some apparent benefits and conveniences of learning from videos. These include accessing content at any time, from any place, the ability to pause, review, slow down, skip and skim through the content, to interact with and watch the content many times. The potential challenges of the study included large class size, students not able to attend for valid reasons, students looking for flexibility, and students who were non-native speakers unable to fully understand the instructions or participate in the interaction process. However these challenges did not distract the researchers of this study from the basic dialogue of learning —-these issues were balanced with in-class active learning. The researchers of this study were mindful of the apparent disadvantage of introducing videos in the active learning class. While video use in class can broaden the learning experience, we were also aware that it might lead to a downgraded pedagogical interaction, challenging the

Dependent Variable: final class grade

Source	Type III Sum of Squares	*df*	Mean Square	*F*	*p*	Partial Eta Squared	Noncentrality. Parameter	Observed Power[b]
corrected model	73.367[a]	1	73.367	62.570	.000	.013	62.570	1.000
intercept	43324.388	1	43324.388	36948.237	.000	.882	36948.237	1.000
type of class	73.367	1	73.367	62.570	.000	.013	62.570	1.000
error	5786.632	4935	1.173					
total	49150.065	4937						
corrected total	5859.999	4936						

a. R Squared = .013 (Adjusted R Squared = .012)

b. Computed using alpha = 0.05

Table 2. Tests of Between-Subjects Effects of Class Type

Dependent Variable: final class grade

year	*M*	*SD*	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
2006	2.75	.100	2.555	2.948
2007	3.05	.046	2.963	3.142
2008	3.16	.053	3.058	3.264
2009	2.90	.064	2.774	3.024
2010	3.05	.040	2.972	3.129
2011	3.27	.054	3.165	3.378
2012	3.14	.100	2.946	3.337
2013	3.56	.115	3.337	3.789

type of class = experimental

Table 3. Tests of Between-Subjects Effects of Years (Long-term results)

Dependent Variable: final class grade						
Bonferroni						
(I) year	(J) year	Mean Difference (I-J)	Std. Error	*p*	95% Confidence Interval Lower Bound	Upper Bound
2013	2006	.8116*	.15277	.000	.3338	1.2894
	2007	.5109*	.12403	.001	.1230	.8988
	2008	.4025*	.12671	.042	.0062	.7987
	2009	.6638*	.13177	.000	.2517	1.0759
	2010	.5130*	.12205	.001	.1313	.8946
	2011	.2915	.12742	.623	-.1070	.6900
	2012	.4216	.15244	.160	-.0551	.8984
type of class = experimental						

Table 4. Multiple Comparisons[a]

An annual (or yearly) comparison between the traditional versus the experimental methods of learning is presented (Table 5).

	class type	*N*	*M*
2006	traditional	173	2.88
	experimental	187	2.75
2007	traditional	337	2.83
	experimental	339	3.05
2008	traditional	435	3.14
	experimental	446	3.16
2009	traditional	295	2.70
	experimental	302	2.90
2010	traditional	329	2.73
	experimental	322	3.05
2011	traditional	364	2.21
	experimental	372	3.27
2012	traditional	374	2.66
	experimental	379	3.14
2013	traditional	142	2.59
	experimental	141	3.56

Table 5. Descriptive Statistics of Independent Variable Yearly (Annual) Comparison

reasons for its implementation – such as reduced lecture attendance. However, no significant decline in student' attendance or interest in the experimental student-centered classrooms were observed by the researchers of this study, following introduction of supplemental videos.

Limitations Of The Study

The results of this study were as expected, the hypothesis was proven as correct (there is a significant difference in student achievement when different teaching methodologies were used), and the results were supported by the review of literature on active learning for the development of curriculum in engineering education. However, the study was not without limitations:

1. Creating an active, student-centered class is not an easy task for an educator. It takes formal training, experience, and a commitment in terms of willingness to make a change in personal perspectives and also in terms of time and effort. A novice attempt at creating such an environment could very well not meet the standards of experimental validity.
2. The sample was not a cross-sectional representation of overall college student populations. The gender ratio strongly favored males, with 4,282 (86.7%) males and 655 (13.3%) females. Although the gender ratio is considerably less female than the campus as a whole (44%) and less than the majority female population of academics nationally, the sample gender distribution in this study more closely reflects the representation of female students within engineering majors.
3. Participants were all learning from a single content domain—statics of engineering.
4. The principal objective of this study was to investigate and evaluate outcomes of the experimental student-centered pedagogy class in terms of student understanding and data collected over seven years—from Fall 2006 to Spring 2013. Any known difference between fall and spring semesters' cohorts may be a limitation to this study, but was not considered as a potential confounding variable.
5. There may be limited generalizability and a potential for bias from the findings of this study due to the absence of a randomization of the selected sample participants. This is due to the facts that: 1) class sections were selected by individual students and/or their academic advisors and 2) selection of the experimental pedagogy class was that of the researcher in accordance to teaching assignments assigned by the department administrators.

Due to these limitations of this study, caution should be exercised when generalizing the findings of this study to other populations.

Conclusions

This study was performed to answer the research question - is there a significant difference in student performance in IFEM statics classes using traditional and experimental teaching methods? The traditional, teacher-centered, 50-minute, 3 times a week classes (passive learning) and the experimental, student-centered pedagogy, 50-minute, 3 times a week classes, were compared for effectiveness. The active learning methodology involved interventions including supplemental videos and interactive-teaching style (active learning) as escalation of active-learning interventions, and these interventions were injected from one cohort to the next. The results as tested using an independent samples t-test and validated using a non-parametric independent samples test and a general linear univariate model analysis, overwhelmingly showed that there was a statistically significant difference between classes taught passively using the teacher-centered pedagogy and classes taught actively using the student-centered pedagogy, as summarized below:

1. The type of class (traditional or experimental) does predict performance across course grades in statics of engineering.
2. High levels of intervention, which involved the full usage of active learning pedagogies of think-pair-share, one-minute points, peer teaching, and problem solving in groups, and supplemental videos of active

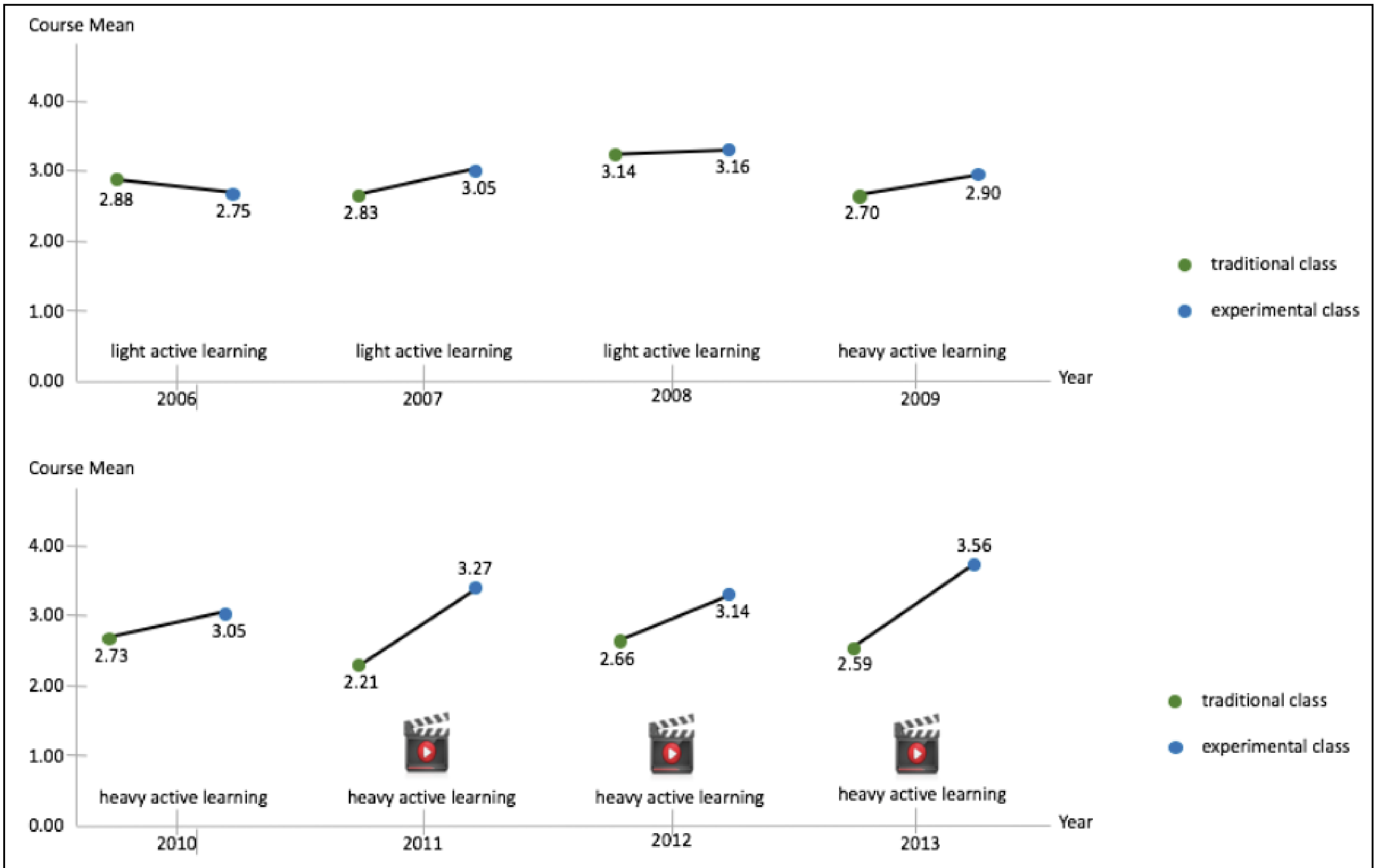

Figure 2. Results of nonparametric independent sample tests of the dependent variable.

learning, are associated with a statistically significant difference in learning or performance, compared to lower levels of intervention of active learning with limited collaboration in the experimental classes.

Recommendations To Faculty And Future Researchers

The authors' recommendation is that large IFEM classes in statics, mechanics, or dynamics do not have to be a challenge or obstacle to engineering education. Any faculty member having the privilege teaching such classes can restructure the course following student-centered pedagogies and simultaneously benefit from the chance to experience a renewed craft of teaching, introducing new and active ways of student interaction. The following recommendations are based on the conclusions of this study:

1. Engineering faculty should be encouraged to use student-centered pedagogies in their classroom instruction, particularly in IFEM classes.
2. Resources and support within engineering departments should be made available for engineering faculty so that the teaches can learn how to implement student-centered pedagogies in their classrooms.
3. Further study is needed to determine which student-centered strategies engineering professors are most comfortable with and can use most effectively.
4. Further study is also needed to determine which student-centered strategies have the greatest impact on student learning.
5. Future studies and research can determine which training techniques are most effective in working with engineering faculty to increase their use of student-centered strategies.
6. Future studies can determine the effects of student-centered learning on dynamics and mechanics education and training .
7. Further study is needed to determine the effects of student-centered learning in upper-level major classes or at a higher post-graduate level.
8. Future research studies are needed to explore the correlation of student-centered learning in IFEM classes with critical thinking in upper-level major classes.
9. Further study is needed to explore the effects of active learning pedagogies on gender and ethnicity.
10. Pedagogical studies in the future must also determine the effectiveness of certain types of presentation of information, via supplemental videos and also determine the measurable effects of including such videos as a structural element within the active learning courses (including change in student attitudes, activities or performance).

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Dr. Peggy C. Boylan-Ashraf is an Assistant Professor in General Engineering at San Jose State University. She teaches structures courses and researches on new paradigms in teaching introductory solid mechanics courses with an emphasis on large enrollments. Over her years of teaching, Dr. Boylan-Ashraf has taught over 6,500 students and has been awarded numerous teaching awards by her students, department, and college.