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Scaffolding in Introductory Engineering Courses

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Abstract

In the past ten years, engineering classrooms have seen an exponential growth in the use of technology, more than during any other previous decade. Unprecedented advancements, such as the advent of innovative gadgets and fundamental instructional alterations in engineering classrooms, have introduced changes in both teaching and learning. Student learning in introductory, fundamental engineering mechanics (IFEM) courses, such as statics of engineering, mechanics of materials, dynamics, and mechanics of fluids, as in any other class, is influenced by the experiences students go through in the classroom. Thus, bold new methodologies that connect science to life using student-centered approaches and scaffolding pedagogies need to be emphasized more in the learning process. This study is aimed to gain insight into the role of student-centered teaching, particularly the implementation of scaffolding pedagogies into IFEM courses. This study also attempts to contribute to the current national conversation in engineering education of the need to change its landscape—from passive learning to active learning. Demographic characteristics in this study included a total of 3,592 students, of whom 3,160 (88.0%) are males and 432 (12.0%) are females, over a period of six years, from 2007 to 2013. The students' majors included aerospace engineering, agricultural engineering, civil engineering, construction engineering, industrial engineering, materials engineering, and mechanical engineering. Results of the study, as tested using a general linear univariate model analysis, indicated that overwhelmingly the type of class in statics of engineering is a significant predictor of student "downstream" performance in tests measuring their knowledge of mechanics of materials. There is a statistically significant difference in students' performance in mechanics of materials depending on whether they were taught passively using the teacher-centered pedagogy or taught actively using the student-centered pedagogy in statics of engineering. Mechanics of materials is commonly the next immediate course, or a downstream course, following statics of engineering.

Keywords

engineering, scaffolding, introductory

Disciplines

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Comments

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Abstract

In the past ten years, engineering classrooms have seen an exponential growth in the use of technology, more than during any other previous decade. Unprecedented advancements, such as the advent of innovative gadgets and fundamental instructional alterations in engineering classrooms, have introduced changes in both teaching and learning. Student learning in introductory, fundamental engineering mechanics (IFEM) courses, such as statics of engineering, mechanics of materials, dynamics, and mechanics of fluids, as in any other class, is influenced by the experiences students go through in the classroom. Thus, bold new methodologies that connect science to life using student-centered approaches and scaffolding pedagogies need to be emphasized more in the learning process. This study is aimed to gain insight into the role of student-centered teaching, particularly the implementation of scaffolding pedagogies into IFEM courses. This study also attempts to contribute to the current national conversation in engineering education of the need to change its landscape—from passive learning to active learning. Demographic characteristics in this study included a total of 3,592 students, of whom 3,160 (88.0%) are males and 432 (12.0%) are females, over a period of six years, from 2007 to 2013. The students' majors included aerospace engineering, agricultural engineering, civil engineering, construction engineering, industrial engineering, materials engineering, and mechanical engineering.

Results of the study, as tested using a general linear univariate model analysis, indicated that overwhelmingly the *type of class* in statics of engineering is a significant predictor of student "downstream" performance in tests measuring their knowledge of mechanics of materials. There is a statistically significant difference in students' performance in mechanics of materials depending on whether they were taught passively using the teacher-centered pedagogy or taught actively using the student-centered pedagogy in statics of engineering. Mechanics of materials is commonly the next immediate course, or a downstream course, following statics of engineering.

Introduction

IFEM classes, which include statics of engineering, mechanics of materials, dynamics, and mechanics of fluids are essential components of many engineering disciplines (Steif & Dollar, 2008). This study is an evaluation of a new paradigm incorporating a pedagogical reform that was performed over a period of six years at Iowa State University (ISU) in its College of Engineering. The focus of the new paradigm was on using student-centered and scaffolding learning approaches to promote better understanding of conceptual fundamental knowledge for students and to see whether there were significant predictors in student performance from an upstream class (statics of engineering) to a downstream class (mechanics of materials) in the same sequence.

For many decades now, engineering education has heard some loud discussions of a new learning paradigm, which involve learning-centered community in classrooms, transformational faculty development, and institutional change (Mayer et al., 2012). These discussions are centered around two popular paradigms—*teacher-centered learning* and *student-centered learning* (Huba & Freed, 2000). The teacher-centered paradigm involves knowledge transmission from teacher to students who passively receive information. In the teacher-centered paradigm, assessments are used to monitor learning with an emphasis on getting the correct answer and the learning culture is competitive and individualistic. These features are contrasted by the student-centered paradigm, which actively involves students in constructing knowledge. The student-centered method emphasizes generating questions, learning from errors, and assessments that are used to diagnose and promote learning. The student-centered culture is cooperative, collaborative, and supportive—wherein both the students and instructor learn (Huba & Freed, 2000). For many decades experiments on a new paradigm involving learning-centered community have been numerously performed, however none in the size and scope of this study. The authors wish to demonstrate and replicate the positive effectiveness of scaffolding in small classes by demonstrating it over 6 years, involving thousands of students.

This quantitative study was designed to explore variables affecting student academic success, with the hope of effectively investigating the most fruitful way to teach IFEM courses, and to determine whether an experimental pedagogy class centered on scaffolding and cooperative learning pedagogies is a strong predictor of student performance. The variables included demographic characteristics and grades earned in two classes—the upstream class (statics of engineering) and the downstream class (mechanics of materials). This study was conducted using data over a period of 6 years, from 2007 to 2013, in both statics of engineering (EM 274) and mechanics of materials (EM 324) at Iowa State University from multiple instructors teaching multiple sections.

In the past, statics of engineering has often been taught in a traditional lecture and note-taking approach. This study echoes the works of others in the field of engineering education and makes use of student-centered learning in statics of engineering (Benson, Orr, Biggers, Moss, Ohland, & Schiff, 2010). The key element of this study is the use of *active and cooperative engagements* in class.

Literature Review

Scaffolding in Teaching

The concept of scaffolding in recent years has become the topic of much discussion and the focus of new research in engineering education. Researchers and educators (Mayer et al., 2012; Schmidt, Loyens, Van Gog, & Paas, 2007) are beginning to take a new perspective to understand the nature and the importance of scaffolding and how it ties with student-centered learning. Scaffolding refers to the "learning supports and aids put in place to allow students to more easily come to grips with new course material that would otherwise be too complex to readily understand" (Putnam, O'Donnell, & Bertozzi, 2010, p. 2) and that "scaffolding works by reducing the amount of cognitive effort that students must expend to learn the materials; by providing students with concepts beforehand, students' attentional processes can be focused on the problem rather than on knowledge acquisition" (Mayer et al, 2012, p. 2507).

The Old Lecture

Herr (1991) noted that the lecture is the most commonly used instructional method in academia and will remain so for a long time—engineering classes included.

Appropriate uses of lecture are to collect, organize and report materials on a topic; to demonstrate enthusiasm for the subject and to share personal experiences related to the subject; to explain complex concepts and ideas introduced in the reading; and to suggest appropriate contexts for such concepts (Cooper & Robinson, 2000). Lecture preparation is also a useful tool for faculty to reflect on the course content. With its own inherent advantages, the lecture mode of instruction has been the conventional way of teaching classes in engineering and has always been credited with being able to cover more information compared to an active and cooperative mode of instruction (Cooper & Robinson, 2000), which takes relatively more time. The lecture method has also been criticized for covering too much information by supporters of the student-centered instructional pedagogies supporters, who stress the importance of covering subjects more in-depth instead of rushing through the topics (Steward-Wingfield & Black, 2005).

The New Student-Centered Learning Lecture

Currently, the cooperative learning model appears to be the center of attention in the discussion of teaching IFEM classes, such as statics of engineering, mechanics of materials, dynamics, and mechanics of fluids (Felder & Brent, 2001). Cooperative learning is an ecological model, where building an open-minded, trusting climate of social interdependence is emphasized (Schul, 2011). The concept of cooperative learning has a strong theoretical base going back to the work of Deutsch around 1920 with research on specific classroom applications beginning around 1970 (Slavin, 1991). According to Slavin, to establish such a climate of inquiry, participants must accept certain responsibilities and interact in certain ways. Learners comfortable with passively listening and memorizing will not easily take to being challenged as proactive learners. They will be at the least anxious, and more likely resistant, resentful, or angry (Slavin, 1991).

For the engineering educator, the power of cooperative learning is not easy to harness. It takes extensive training, practice, and preparation time; and for the neophyte faculty member, this can be highly time-consuming (Felder & Brent, 2001). Foremost it requires major change in personal perspective. No longer is an instructor the subject matter expert, up front and in control, but instead instructors become facilitators, resource providers, and process evaluators (Schul, 2011)—skills most new faculty do not have, have not practiced, and often do not feel comfortable performing. Thus, when applying cooperative learning in IFEM classes, one must be cognizant of the five suggested elements according to the Johnson and Johnson model (Johnson & Johnson, 1984):

1. Learners must develop a sense of belonging and be taught the social skills necessary for collaborative effort, such as leadership, listening, reflecting, and conflict resolution.
2. Learners must have face-to-face interaction. If together students do not explain, argue, formulate, and reach a consensus on results/methods, the overwhelmingly positive cognitive and affective outcomes of cooperative learning will not be realized. This is an application of the old saying: "When you teach, you learn".
3. Each participant must pull his/her own weight. Task assignments and evaluation and feedback, both from the instructor and peers, must assure individual accountability for every student.
4. Learners must process and reflect on their group's interaction. This involves how well they are working together and how they can improve.
5. Learners must work toward positively interdependent goals. Students must be as concerned with the learning performances of their peers as they are about their own.

The effects of cooperative learning have been researched by numerous scholars (Cooper & Robinson, 2000; Davidson & Worsham, 1992; Nagel, 2008; Slavin 1991; Slavin & Oickle, 1981) for many decades with student levels ranging from pre-schoolers to college undergraduates. Slavin (1991) looked thoroughly at sixty studies in elementary and secondary schools with treatment and control groups that studied the same objectives for at least four weeks. Johnson and Johnson (1984) worked over a period of twelve years on 521 studies chosen from over 1000 articles, with subjects across all levels of education (pre-schoolers to college undergraduates). All these scholarly studies showed that *if* the elements of positive interdependence and individual accountability are present, cooperative learning consistently promotes higher achievement. In regard to achievement, "the evidence is overwhelming that cooperation is effective for a wide range of goals, tasks, technologies, and individuals of different achievement levels, backgrounds, and personalities" (Johnson & Johnson, 1984, p. 170). "Achievement effects of cooperative learning have been found to be about the same degree at all grade levels, in all major subjects" (Slavin, 1991, p.71). Slavin continued by saying, "Effects are equally positive for high, average, and low achievers" (Slavin, 1991, p. 71).

Johnson and Johnson (1984) stressed the presence of considerable face-to-face interaction and group processing to improve overall group functioning as also being important for achievement gains. With the additional presence of these elements, cooperative learning resulted in more frequent use of high-quality reasoning strategies, more frequent transition to higher-level reasoning, and more frequent use of meta-cognitive strategies (Johnson & Johnson, 1984; Slavin, 1991). Equally important, both Slavin and Johnson and Johnson consistently found positive effects for improved interpersonal relations, higher motivation to learn (especially intrinsic motivation), higher levels of self-esteem, and enhanced multi-ethnic relationships where participants have differentiated, dynamic, and realistic views of others as opposed to static stereotypical views. Slavin (1991) stated, "Although not every study has found positive effects on every non-cognitive outcome, the overall effects of cooperative learning on student self-esteem, peer support for achievement, internal locus of control, time-on-task, liking of class and classmates, cooperativeness, and other variables are positive and robust" (p. 53).

Thus, one of the main challenges of this study was to devise a scaffolding and cooperative learning strategy that not only enhances the experience and effectiveness but also remains within the usual class time period as in a regular lecture format. How scaffolding affects student learning and how can scaffolding and cooperative learning concepts be incorporated into IFEM classes, such as statics of engineering, mechanics of materials, dynamics, and mechanics of fluids without a huge shift from the conventional methods of instruction are the questions that this article attempts to answer.

Research Question

This study sought to answer the research question *do scaffolding and cooperative learning improve student ability in the next class in the same sequence?*

Methodology

Population

The population of this study was engineering students enrolled at ISU. Located in Ames, Iowa, ISU, ranks in the top twenty in engineering bachelor degrees awarded in aerospace, chemical, civil, industrial and manufacturing, mechanical, and computer engineering (Iowa State University website, 2013). The sample population, from which the respondents were drawn, are students enrolled in both statics of engineering (EM 274) and mechanics of materials classes from spring 2007 to spring 2013. The sample consisted of a total of 3,592 students, of whom 3,160 (88.0%) are males and 432 (12.0%) are females. The students' majors included: aerospace engineering, 617 students (17.2%); agricultural engineering, 180 students (5.0%); civil engineering, 655 students (18.2%); construction engineering, 420 students (11.7%); industrial engineering, 22 students (0.6%); materials engineering, 197 students (5.5%); and mechanical engineering, 1434 students (39.9%). There were 67 students (1.9%) who enrolled outside the majors mentioned above.

Design and Procedure

This study aimed to answer the overarching question of whether the type of class—1) passive instructional method using the teacher-centered pedagogy or 2) *active* instructional method using the student-centered pedagogy in statics of engineering is a significant predictor of

Class Type in Statics	2007	2008	2009	2010	2011	2012	2013
Experimental	178 (Z)	219 (Z)	229 (Z)	245 (Z)	270 (Z)	259 (Z)	339 (Z)
Traditional	181 (CEH)	235 (DF)	248 ADIJ	261 (BEG)	295 (AC)	287 (AFIJ)	346 (ADEH)

Table 1. Number of Students and Instructors in Statics of Engineering

student performance in mechanics of engineering. The passive instructional method using the teacher-centered pedagogy is the traditional 50-minute, three times a week class and the active instructional method using the student-centered pedagogy is an experimental 50-minute, three times a week class, that involved interventions and scaffolding approaches, including supplemental videos and interactive-teaching style. The comparison was designed to focus on student final class grades.

Passive learning featured in this study is the typical lecture format, wherein the instructor speaks at the front of the room and the class sits facing the instructor. Interaction between instructor and students often appeared stiff and limited to questions and answers. The typical lecture format limited interaction among students during class time.

Active learning, on the other hand, as implied by its very title, is something "other than" the traditional lecture format. The concept of active learning in this study is simple, rather than the instructor presenting facts to the students, the students played an active role in learning by exploring issues and ideas under the guidance of the instructor (scaffolding). Instead of memorizing, and being mesmerized by a set of often loosely connected facts, the students learned a way of thinking, asking questions, searching for answers, and interpreting observations within their learning groups during class (cooperative learning).

In this research, a cross sectional, ex-post facto study was carried out on two groups of participants over the period of six years, from spring 2007 to spring 2013: 1) undergraduate students at ISU, who were enrolled in the traditional (passive learning) pedagogy statics of engineering and also mechanics of materials classes from spring 2007 to spring 2013 and 2) undergraduate students at ISU, who were enrolled in the experimental (active learning) pedagogy statics of engineering and also mechanics of materials classes from spring 2007 to spring 2013. Student-centered pedagogy of active learning (experimental group) versus teacher-centered pedagogy of passive learning (traditional group) were only differentiated in statics of engineering, not in mechanics of materials. The mechanics of materials classes were all taught using the teacher-centered pedagogy throughout the 6 years of this study.

Independent Variable

The independent variable used in this study is *class grades in statics of engineering*. There were 2 types of classes in statics of engineering: the passive learning classes and the active learning classes. Additional covariates, described below, also were incorporated into the model, to account for the role of individual student differences and to adjust for potentially confounding variables.

Dependent Variable

The dependent variable used in this study is *class grades in mechanics of materials.*

A student database was obtained from the Office of the Registrar at ISU. One of the authors (Instructor Z) of this paper taught the experimental, student-centered pedagogy classes in statics of engineering continuously each semester, from spring 2007 to spring 2013. Ten members of the faculty (Instructors A-J) of the aerospace engineering department at ISU taught the traditional, teacher-centered pedagogy classes in statics of engineering and also all of the mechanics of materials classes, from spring 2007 to spring 2013. A breakdown of the number of students as well as instructors taught is shown in Table 1 above.

Instructor Z who taught all the sections and classes of statics of engineering through this study was a graduate student/lecturer. Instructors A-J who taught all the sections and classes of statics of engineering and mechanics of materials were senior tenured professors. Due to the numerous instructors involved in this study, both classes were designed with as many similarities as possible. Both classes shared same syllabus in all their respective sections; all instructors covered the same material throughout the semester; all sections used the same textbook, all instructors gave identical exams throughout the semester, all sections were aided by the same teaching assistants, all instructors used the same grading scheme (deducted the same number of points during examinations and homework) and grading scale. These similarities occurred throughout the entire study. In addition, an analysis of variance was conducted to see if there were substantial differences in student performance across the 10 traditional instructors. There was not a significant difference ($p > 0.05$) that would provide evidence to support a conclusion that within-group differences (across traditional instructors in statics of engineering) were important.

The independent and dependent variables of grade performance is measured on an ordinal grading scale ranging between 0.00 (F) and 4.00 (A).

Data Analysis

This study employed an independent samples t-test, a nonparametric independent samples test, and a general linear univariate model analysis to understand the outcome of student learning effectiveness concerning the impact of learning interventions in a downstream class (mechanics of materials) using student-centered pedagogy on their academic learning in the upstream class (statics of engineering). With the hope of effectively investigating the most fruitful way to teach IFEM courses, this study aimed to answer the overarching question of whether the type of class in statics of engineering—1) the *traditional* 50-minute, three times a week classes (passive, teacher-centered learning pedagogy) or 2) the *experimental* pedagogy, 50-minute, three times a week classes, which involved interventions including scaffolding (e.g., think-pair-share, one-minute muddiest point, and problem solving in groups (Angelo & Cross, 1993), supplemental videos and interactive-teaching style (active, student-centered learning pedagogy)—is a significant predictor of student performance in the mechanics of materials class. Quantitative data collection was employed, 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 statistical analysis and all results are presented in aggregate form such that no individuals can be identified. This ensured that the investigators of this project cannot identify the individuals to whom the data pertain. An exempt classification for the human subjects research was obtained from the ISU Institutional Review Board.

Results and Discussion

Out of the 3,592 cases (students enrolled in both statics of engineering and mechanics of materials) analyzed in this study, 289 cases (8.05%) were missing data on pre-college performance. This percentage (8.05%) of students in the entire dataset was similar to the percentage of international student in the traditional class (7.96%) and the experimental class (8.09%) in statics of engineering. Missing data are frequently encountered and occur in all types of studies, no matter how strictly designed or how hard investigators try to prevent them (Burns et al., 2011; King, 2001; Olinsky, Chen & Harlow, 2003; Rubin, 2004). When predictors and outcomes are measured only once (such as in this study), *multiple imputation of missing val-*

ues is the advocated approach (King, 2001; Rubin, 2004). In this study, most of the missing data were highly associated with international students; thus trimming the 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 (Version 21) 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 and replace them to create a full data set. In this study, five imputations were used and they were performed in sequence. During each imputation simulation, the missing data were generated to create a model and at the end of the fifth imputation simulation, the values of the five imputations were averaged to take into account the variance of the missing data. This study presents only results of the fifth imputation.

Comparing pre-college performance in Table 2, it is seen that students who were enrolled in the experimental class (active, student-centered learning pedagogy) in statics of engineering started with a slight deficit entering college compared to those who were enrolled in the traditional class (passive, teacher-centered learning pedagogy) in statics of engineering. All the pre-college variables, which included high school grade point average; ACT (American College Testing) subject scores in English, mathematics, and the composite ACT; SAT (Scholastic Aptitude Test) scores in verbal and mathematics subject scores, showed slightly lower means for students enrolled in the statics of engineering experimental class. The deficit in each category is statistically insignificant ($p > 0.05$). It may be interpreted that students in both groups started at the same level entering college, which established the equality of the 2 groups at baseline, before treatment of the active-learning intervention.

An independent samples *t*-test was conducted to determine if there was a difference in student performance in the upstream class (statics of engineering) between those who were taught using the active, student-centered approach and those taught using the passive, teacher-centered approach. The results show that there was a *statistically significant difference* in the scores in *course grade in statics of engineering* between the experimental, active, student-centered class of statics of engineering (M=3.24) and for the traditional, passive, teacher-centered class of statics of engineering (M=3.13); $t(3573.539)=4.062$, $p < .001$ as seen in the results summarized in Tables 3 and 4. The effect size for this difference was calculated as 0.1348.

These results suggest that active, student-centered pedagogies do have an effect on student performance. In addition, the analyses indicate that even though students who were enrolled in the experimental class of statics of engineering tend to have a slight deficit from their pre-college performances as seen in Table 2, they performed better in their college class of statics of engineering, as seen in Tables 3 and 4, when subjected to interventions of active learning pedagogies. The deficit in pre-college performances, as seen in Table 2, is statistically not signifi-

Imputation		Class Type in Statics	N	M	SD
5	HS GPA	Experimental	1804	3.70	.36901
		Traditional	1788	3.72	.35631
	ACT English	Experimental	1804	25.09	4.566
		Traditional	1788	25.58	4.779
	ACT Mathematics	Experimental	1804	28.03	3.729
		Traditional	1788	28.33	3.879
	ACT Composition	Experimental	1804	26.59	3.548
		Traditional	1788	26.94	3.768
	SAT Verbal	Experimental	1804	583.01	38.368
		Traditional	1788	585.84	36.685
	SAT Mathematics	Experimental	1804	653.05	27.846
		Traditional	1788	655.36	29.507
	SAT Combination	Experimental	1804	1236.06	55.313
		Traditional	1788	1241.19	56.832

Table 2. Descriptive Statistics of Pre-College Variables

Imputation		Class Type in Statics	*N*	*M*	*SD*
5	Course Grades in Statics	Experimental	1804	3.24	.79163
		Traditional	1788	3.13	.83978

Table 3. Descriptive Statistics of Course Grades in Statics between Class Types

Imputation			Levene's Test		*t*-Test						
			F	*p*	*t*	*df*	*p*	Mean Difference	Std. Error	95% CI Lower	95% CI Upper
5	Course Grade in Statics	Equal variances assumed	9.625	.002	4.063	3590	.000	.11063	.02723	.05724	.16401
		Equal variances not assumed			4.062	3573.539	.000	.11063	.02724	.05723	.16403

Table 4. Independent Samples t-Test of Course Grades in Statics between Class Type

Imputation		Class Type in Statics	*N*	*M*	*SD*
5	Course Grade in Mechanics	Experimental	1804	2.57	1.18706
		Traditional	1788	2.49	1.19403

Table 5. Descriptive Statistics of Course Grades in Mechanics of Materials between Class Types in Statics

Imputation			Levene's Test		*t*-Test						
			F	*p*	*t*	*df*	*p*	Mean Difference	Std. Error	95% CI Lower	95% CI Upper
5	Course Grades in Mechanics	Equal variances assumed	.223	.637	2.124	3590	.034	.08437	.03973	.00647	.16226
		Equal variances not			2.124	3589.966	.034	.08437	.03973	.00648	.16226

Table 6. Independent Samples t-Test of Course Grades in Mechanics between Class Types in Statics

cant (p > 0.05). It may be concluded that students in the traditional and experimental groups started at the same level entering their engineering journey.

Two measures were taken to answer the overarching question of whether the type of upstream class (statics of engineering)—1) the traditional 50-minute, three times a week classes (passive, teacher-centered learning pedagogy) or 2) the experimental pedagogy, 50-minute, three times a week classes, which involved interventions including scaffolding, supplemental videos and interactive-teaching style (active, student-centered learning pedagogy)—is a significant predictor in the downstream class (mechanics of materials).

First, an independent samples t-test was conducted to see if there was a difference in student performance in mechanics of materials between students taught using the active, student-centered approach in statics of engineering and students taught using the passive, teacher-centered approach in statics of engineering. Indeed, there was a *statistically significant difference* in the scores in *course grade in mechanics of materials* for the students enrolled in the experimental, active, student-centered class of statics of engineering (M=2.57) and for the students enrolled in the traditional, passive, teacher-centered class of statics of engineering (M=2.49); $t(3590)=2.124$, $p = .034$, as seen in Tables 5 and 6. The Cohen's d effect size for this data was 0.0672.

Due to violations of normality when examining a histogram of the dependent variable, the independent samples *t*-test of Tables 5 and 6 was validated using a nonparametric

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of **Course Grade in Mechanics** is the same across categories of **Class Type in Statics**.	Independent-Samples Mann-Whitney U Test	.022	Reject the null hypothesis.

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

Figure 1. Results of nonparametric independent samples test of grades in mechanics of materials from SPSS (Version 21).

Tests of Between-Subjects Effects

Dependent Variable: course grades in mechanics of materials

Imputation	Source	Type III Sum of Squares	*df*	Mean Square	*F*	*p*	η²	Noncentrality Parameter	Observed Power[b]
5	Corrected Model	1269.005[a]	10	126.900	118.775	.000	.249	1187.745	1.000
	Intercept	9.228	1	9.228	8.637	.003	.002	8.637	.836
	Course Grade in Statics	1217.356	1	1217.356	1139.404	.000	.241	1139.404	1.000
	Major	19.491	7	2.784	2.606	.011	.005	18.243	.899
	Gender	.342	1	.342	.320	.571	.000	.320	.087
	Class Type in Statics	22.363	1	22.363	20.931	.000	.006	20.931	.996
	Error	3825.992	3581	1.068					
	Total	28101.858	3592						
	Corrected Total	5094.997	3591						

a. R Squared = .249 (Adjusted R Squared = .247)

b. Computed using alpha = 0.05

Table 7

independent samples tests, as seen in Figure 1.

The reason this study uses a nonparametric independent samples test is because this approach tests hypotheses while not making assumptions about the population parameters. This approach has the advantage that it applies to a more general condition than do parametric tests (such as the independent samples t-test explained earlier). After observations of histograms of both the independent and dependent variables are clear they show no trend of normal distribution, a nonparametric test was justified. The Mann-Whitney customized test was chosen in SPSS (Version 21) while performing the nonparametric independent samples test.

The result of Figure 1 suggests that indeed the hypothesis concerning the distribution of grades in mechanics of materials is the same across categories of class type in statics of engineering is rejected ($p < 0.05$).

Second, a general linear univariate model analysis, as seen in Table 7, was used to estimate the impact on student learning effectiveness of learning interventions in the downstream class (mechanics of materials) using student-centered pedagogy on their academic learning in the upstream class (statics of engineering). Student major, gender, and course grade in statics of engineering were incorporated into the model to control for possible sources of confounding.

The results in Table 7 reconfirmed the independent samples t-test and the nonparametric independent samples test, in demonstrating that the type of class in statics of engineering—the experimental class (active, student-centered learning pedagogy) or the traditional class (passive, teacher-centered learning pedagogy) is a significant predictor of student performance in mechanics of materials. In addition, these results show that course grade in statics of engineering and major are also significant predictors in performance in mechanics of materials; while gender is not a significant predictor.

Limitations of Study

The results of this study were as expected and were supported by the literature regarding student-centered 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 perspective and in terms of time and effort. A novice attempt at creating such an environment could very well not meet standards of treatment fidelity.
2. The sample was not a cross-sectional representation of overall college student populations. The gender ratio strongly favored males, with 3,160 (88.0%) males and 432 (12.0%) females. Although the gender ratio is considerably less female than the campus as a whole (44%) and less than the majority female population of academic generally, the sample gender distribution more closely reflects the representation of female students within engineering majors.
3. The differences of engineering majors analyzed in this study, although was a predictor of student performance, is not part of the hypothesis of this paper, and thus is not pursued in its discussions.
4. Participants were all learning from a small content domain of engineering mechanics courses, statics of engineering and mechanics of materials.

Conclusions

This study was begun in hopes of being able to answer the overarching research question: *do scaffolding and cooperative learning improve student ability in the next class in the same sequence?* Class type in statics of engineering—whether 1) the traditional 50-minute, three times a week classes (passive, teacher-centered learning pedagogy) or 2) the experimental pedagogy, 50-minute, three times a week classes, which involved interventions including scaffolding, supplemental videos and interactive-teaching style (active, student-centered learning pedagogy)—is a significant predictor of student performance in mechanics of materials. In addition, grades in statics of engineering, as well as students' major, are also clearly significant predictors of performance in mechanics of materials, as summarized below:

1. The type of class (experimental or traditional) in statics of engineering is a statistically significant predictor of performance in mechanics of materials.
2. Performance in statics of engineering is a statistically significant predictor of performance in mechanics of materials.
3. Major is a statistically significant predictor of performance in mechanics of materials.
4. Gender is not a statistically significant predictor of performance in mechanics of materials.

Recommendations to Faculty and Future Researchers

Thus, the authors' recommendation is that large IFEM classes, such as statics of engineering, mechanics of materials, dynamics, and mechanics of fluids do not have to be engineering's workhorse. Any faculty member having the privilege of teaching them can restructure the course following student-centered pedagogies and simultaneously benefit by the chance to experience a renewed craft of teaching. The following recommendations are based on the conclusions of this study:

1. Engineering faculty should be encouraged to use scaffolding and cooperative learning pedagogies in their classroom instruction, particularly in IFEM classes.
2. Resources and support within engineering departments should be made available for engineering faculty to 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 use most effectively.
4. Further study is needed to determine which student-centered strategies have the greatest impact on student learning.
5. Further study is needed to determine which training techniques are most effective in working with engineering faculty to increase their use of student-centered strategies.
6. Further study is needed to determine the effects of student-centered learning in dynamics and mechanics of fluids.
7. Further study is needed to determine the effects of student-centered learning in upper-level major classes.
8. Further study is needed to explore the correlation of student-centered learning in introductory, fundamental classes, such as statics of engineering, mechanics of materials, dynamics, and mechanics of fluids with critical thinking in upper-level major classes.
9. Differences across engineering majors analyzed in this study are not part of the hypothesis of this paper, and thus is not pursued herein."

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