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A new paradigm in teaching large engineering mechanics courses

Anne (Peggy) C. Boylan-Ashraf
Iowa State University

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by

Anne (Peggy) C. Boylan-Ashraf

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Program of Study Committee:
Steven A. Freeman, Major Professor
Thomas J. Brumm
Steven K. Mickelson
Mack C. Shelley
Loren W. Zachary

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DEDICATION

I dedicate the completion of this dissertation to my husband and best friend, Raihan Ashraf, who without fail has always taught me that perseverance is a virtue. Because of you I was brave.

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ABSTRACT

This study investigated the role of a new paradigm in teaching large introductory fundamental engineering mechanics courses that combines student-centered learning and supplemental student resources. The sample consisted of close to 5000 engineering students from Iowa State University.

Demographic characteristics in the study included students' major, gender, performance in high school, and achievement and aptitude tests scores. Results of the study overwhelmingly showed that not only is there a difference between a class taught passively using the teacher-centered pedagogy and a class taught actively using the student-centered pedagogy, but also that the usage of the variety of student-centered pedagogies in statics of engineering is a significant predictor in student performance in mechanics of materials.

The principal focus of this work was to determine if the new paradigm was successful in improving student understanding of course concepts in statics of engineering. 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 a reform but hesitant to abandon conventional teaching practices. By promoting a new paradigm, the potential for improving understanding of engineering fundamentals on a larger scale may be realized.

CHAPTER 1. INTRODUCTION

Introduction

Introductory, fundamental engineering mechanics (IFEM) courses, which include statics of engineering, mechanics of materials, and dynamics are essential components to many engineering disciplines (Steif & Dollar, 2008). This dissertation is an evaluation of a new paradigm incorporating a pedagogical reform that was performed over 7 years at Iowa State University in its college of engineering. The focus of the new paradigm was using student-centered learning to promote better understanding of conceptual fundamental knowledge for students.

Student-centered learning was first introduced as early as the 1960s under a reform pedagogy called guided inquiry (Karplus and Their, 1969). It was introduced in 3 phases: an exploration phase, an invention phase, and an application phase. This pedagogy has been found to provide students with a significantly better conceptual understanding compared to students taught traditionally (Barman, Barman, & Miller, 1996; Marek, Cowan, & Cavallo, 1994; Stephans, Dyche, & Beiswenger, 1988).

Traditionally taught students are understood as those whose instruction primarily focuses on verbal and printed words, rote memorization, and is instruction driven (Schneider & Renner, 1980); students are told what they are expected to know, concepts are presented deductively, and the faculty conducts lessons by introducing and explaining concepts to students and then expect students to complete tasks to practice those concepts. Modern interpretations of student-centered learning include project-based learning, case-based learning, discovery, and just-in-time teaching with 3 instructional approaches of active learning, cooperative learning, and problem-based learning (Prince & Felder, 2004).

With the hope of effectively investigating the most fruitful way to teach IFEM courses, and to compare the *traditional* pedagogy, which is the full 50-minute lecture, three times a week class to an *experimental* pedagogy, 50-minute, three times a week class centered on active learning, this quantitative study was designed to explore factors affecting student academic success. The factors included demographic characteristics, grades earned in class including, homework, in-class assignments, and examinations scores. This study was conducted using data from 2 engineering mechanics classes at Iowa State University, statics of engineering (EM 274) and mechanics of materials (EM 324), during a span of 7 years from multiple instructors.

Statics of engineering was chosen because its concepts and applications are needed in almost every discipline of engineering (Benson et al., 2010; Rutz et al., 2003). It is a fundamental prerequisite for subsequent courses such as mechanics of materials, dynamics, and fluid dynamics, and in some programs, other courses such as tool design, etc. (Beer & Johnston, 2004; Orr, Benson, & Biggers, 2008). Many researchers (Beer & Johnston, 2004; Benson et al., 2010; Rutz et al., 2003; Orr et al., 2008) believe that performance in these later courses can be directly correlated to success in statics of engineering.

In the past statics of engineering has often been taught in a traditional lecture and note-taking approach. According to current understanding (Thomas, Subramaniam, Abraham, Too, & Beh, 2011; Zorn & Kumler, 2003), humans think, learn, and solve problems by making connections and associations to previous experiences. Numerous researchers (Gleason, 1986; Thomas et al., 2011; Zorn & Kumler, 2003) have written that if one's first exposure to fundamental concepts takes place by passively hearing it in lecture or by reading it in a textbook, the experience may not be sufficiently significant or rich to build connections. Thus, determining factors that could facilitate academic success in statics of engineering should be a major concern in engineering education.

Background

Engineering has greatly impacted the world since the dawn of time and the quality of life of humanity is highly dependent upon the quality of engineering design and development -- making the education of its students of great importance. Due to the dynamic nature of engineering, the education of these students should include strong fundamentals as well as the establishment of the desire of life-long learning (Goel, 2011). Most engineering educators would agree that educating future engineers in a strong knowledge of fundamentals is no trivial goal; and the task becomes more profound when educating students in large lectures (Hagerty & Rockaway, 2012; Rutz et al., 2003).

Due to budget pressures and the attractive possibility for cost reduction, numerous schools have chosen the route of teaching fundamental classes in large lectures (Cakmak, 2009; Kryder, 2002; Gleason, 1986; Mulryan-Kyne, 2010). As in any debatable topic, the discussion of large lectures has birthed two schools of thoughts. Christopher's (2003, p.1) study found the following:

- The proponents of large lectures argue that large lecture classes generate the numbers, which provide other faculty the opportunity to teach special topic undergraduate and graduate classes that might not otherwise be offered to the student body due to budget and other resource constraints.
- The opponents of the large lecture approach argue that large lecture sections dilute the learning process, place an undue burden on faculty in terms of test monitoring, grading, office hours or student interaction, and course management.

Whichever camp one belongs to, whether one attempts to move toward small lectures or large ones, or one believes more in one idea over the other, there is a perspective that has been long neglected – the students. The central issue is not small versus large lectures, but the effectiveness of student learning.

It is quite true that in large IFEM classes, such as statics of engineering, mechanics of materials, dynamics, and fluid dynamics where a lecture hall could fit as many as 40 to 400 students or more, a very different set of challenges is faced. Faculty teaching these courses with large numbers of students will likely list many of the same types of challenges; among them are: organization of paperwork, management of distractions, anonymity of the students, lack of flexibility in class activities, and diverse background and preparation of the students (Cakmak, 2009; Gleason, 1986; Hejmadi, 2007). Likewise, issues for students arise when one is enrolled in courses with hundreds of other peers; among them are: impersonal atmosphere, minimal contact with faculty, getting "lost in the crowd", low motivation and minimal involvement, and shallowness of understanding (Kryder, 2002; Yazedjian & Kolkhorst, 2007). Whether as a faculty or as a student in a large lecture, numerous studies (Al Nashash & Gun, 2013; Dyrud & Worley, 2002; Fata-Hartley, 2011; Gleason, 1986; Switzer, 2004) have shown over many decades that the quality of education in a large lecture class is not equivalent to that in smaller classes.

Problem Statement

Increasing student involvement through making greater use of active modes of teaching was the major recommendation of the National Institute of Education report about 30 years ago in 1984 as stated in Involvement in Learning: Realizing the Potential of American Higher Education (Study Group on the Conditions of Excellence in American Higher Education, 1984).

Since that time, many learning theorists, faculty development consultants, and reports on higher education have recommended the importance of interactive and participatory student involvement for learning that effects cognitive and effective growth – and literally hundreds of articles have been written on the topic since that report. Yet despite these recommendations, college and university professors continue to lecture –and in some cases, in lecture halls with hundreds and hundreds of students (Hejmadi, 2007). Part of this is due to the lure of economies of scale, which refers to the cost advantages that an enterprise obtains due to expansion (Mulryan-Kyne, 2010). The lecture format is still dominant in many universities and has become the quick and convenient cost-cutting strategy (Kryder, 2002). "Large classes are very prevalent in many universities and are often gateway courses to students' major fields of study" (Stanley & Porter, 2002, p. xxii), and in engineering, its introductory fundamental courses such as statics of engineering, mechanics of materials, dynamics, and fluid dynamics are easy targets of the practice of "herding" students into large classes. This practice can pose quite a difficult adjustment for freshman and sophomore college students.

Cooper and Robinson (2000) artfully expressed the potentially dangerous consequence of subjecting freshman and sophomore college students to large lecture classes:

> A growing body of research points to the value of undergraduate learning environments that set high expectations, promote active and interactive learning, and give students personal validation and frequent feedback on their work. These settings and practices are especially beneficial for beginning learners as they make the transition to college. Yet in most universities, introductory courses that fulfill their curriculum requirements often carry enrollment of hundreds of students. These large-class settings have historically been heavy lectured-centered, requiring minimal student engagement and expecting little

> more than memorization of terms and concepts as evidence of student learning. The sheer size and anonymity of large classes seem to weigh against the very elements that promote students' involvement and intellectual development, learning, and success. Inattention or absence from class and mediocre student performance seem to be tolerated simply as unfortunate realities (Cooper & Robinson, 2000, p.1).

The Purpose of the Study

The purpose of this study is to investigate the most effective way to teach IFEM courses in large lectures and to compare the traditional-style pedagogy, which is the full 50-minute lecture, three times a week class to an experimental pedagogy, 50-minute, three times a week class centered on constructivism learning style. The experimental pedagogy involved focusing on desired learning and made use of active learning and a variety of student-centered techniques to address a broad spectrum of learning styles.

Although large classes pose a different set of issues, which often implies that quality teaching is not possible in large classes, researchers (Cakmak, 2009, Kryder, 2002; Mulryan-Kyne, 2010; Switzer, 2004) in education suggested the contrary, quality teaching is quite possible in large classes while focusing on student-centered, cooperative, active experimentation, and high-level thinking learning, instead of the traditional teacher-centered, individual, reflective observation, and routine-drill learning.

Almost a decade ago, Felder (2004) had recommended the need to change the pedagogy used in engineering classrooms. According to his study at that time, many engineering classes in 1999 were taught in exactly the same way that engineering classes in 1959 were taught and that the existing teaching and learning strategies in engineering programs were outdated and needed to become more student-centered (Felder, 2004). Even today, nine years later, the paradigm of engineering education is still essentially the same and the need to identify an effective and affordable teaching approach applicable for large IFEM courses still exists. Other researchers (Hagerty & Rockaway, 2012; Lindenlaub et al. 1981; Mora, Sancho-Bru, & Iserte, 2012) echo Felder and suggested that the overall goal for a new paradigm is for students to learn and apply a systems approach to engineering problem solving such that when they become practicing engineers they will develop more sustainable solutions.

Research Questions

The research questions explored in this study were:

1. *Do active learning pedagogies in large classes improve student ability to understand course concepts and learn problem-solving measured through semester examination scores, homework scores, and final class grades?*
2. *Do constructivist pedagogies using different levels of interventions improve student performance measured through comparisons of final class grades of different cohorts taught by a single faculty member?*
3. *Do scaffolding and cooperative learning improve student ability in the next class in the same sequence?*

Significance of the Study

As part of a broad effort to improve engineering education, this study will serve as an important piece in understanding ways to promote better understanding of effective teaching, especially in large IFEM classes. While in general it has been shown that intervention or reform style teaching improves academic achievement over traditional lecture-based styles (Adrian, 2010; Rutz et al., 2003; Zorn & Kumler, 2003), this study will be among the first to demonstrate a reform that is specifically tailored to large IFEM classes, particularly statics of engineering.

Statics of engineering continues to be a mainstay of engineering education in many disciplines, forming an important prerequisite for many subsequent courses (Benson et al., 2010; Rutz et al., 2003). With all the wealth of information engineering education researchers know in regard to active learning and teaching styles versus learning styles, statics of engineering is still taught with an emphasis on mathematical concepts. Although mathematical concepts are useful in solving equilibrium problems, statics of engineering should be taught with enough emphasis on modeling and how mechanical systems interact (Benson et al., 2010). Often, students who learn statics of engineering in this traditional way fail to learn to utilize its concepts adequately in the analysis and design of mechanical systems and structures, which they confront subsequently. Moreover, most widely used statics of engineering textbooks follow essentially the same sequence of topics as put forth in the first modern textbooks in the subject dating from the 1950s. This study aims to fill in the knowledge gap of the usage of active learning and its application to statics of engineering, particularly in the context of large lectures; and to effectively measure more deliberate and sequential approaches to addressing concepts of statics of engineering and to expand upon a more student-centered and concept-driven approach to include the full range of ideas and skills that a student needs to effectively learn statics of engineering.

Literature Review

Higher education in the U.S. has many ironies. One is that most professors at leading colleges and universities have no formal training in teaching (Austin, 2002; Felder, 1993). Even to this day, most graduate training programs focus on the development of research and scholarly skills rather than skills related to instruction (Edwards, Jepsen, &Varhegyi, 2012; Monk, Foote, & Schlemper, 2012). As a result, few faculty members have any systematic knowledge or experience in preparing and delivering effective lectures, in leading classroom discussions, or in the mentoring of graduate and undergraduate students (Bishop, Yu, & Kupferle, 2001; Trautman, 2008).

A second irony is that while Ph.D. programs at leading research institutions typically emphasize research and other academic scholarship, only a small percentage of the graduates of these programs actually secure faculty positions at research institutions. Instead, a majority of them go to institutions that place much greater emphasis on teaching as part of the faculty member's roles and responsibilities (Hativa, 1997). One consequence for many of these new graduates is that the transition from graduate student to faculty member is difficult. Most learn how to become an effective teacher on the job (Felder, 1993), devoting much if not all of their first few years as a professor to developing courses, designing and redesigning lectures, and learning solutions to the legion of issues students bring to them in their classes (Bishop et al., 2001).

The third irony is perhaps the most peculiar and tragic of the three. Many institutions (and the academic departments within them) ask their least experienced faculty (typically, new assistant professors or lecturers) to teach large courses in their first few years (Bishop et al., 2001; Felder, 1993). Often these courses have many hundreds of students and are, by virtue of their size, among the most challenging to teach effectively (Cole & Spence, 2012; Hejmadi, 2007; Saunders & Gale, 2012; McKagan, Perkins, & Wieman, 2007). Yet many senior faculty members view teaching these courses as a rite of passage, challenges that all faculty members must experience at early points in their careers regardless of their ability or interest. The practice of "giving" these courses to new junior faculty members is unfortunate. Often they have the least amount of knowledge and experience in teaching in the large class setting (Felder, 1993; Mertz & McNeely, 1990).

These ironies plus the massive shift which is occurring in higher education, driven by complex forces including financial, administrative, and organizational and stakeholder expectations are not only changing the world, but has led to the emergence of educators improving and maintain the quality of teaching and learning outcomes while contending with increasing class size. Large classes will continue to be the cultural norm in higher education, despite of mixed evidence on its effectiveness and student outcomes; but they also provide the push for innovative solutions to overcome challenges.

Definition of Large Classes

Although for many years, researchers have studied the effects of class size on teaching effectiveness and student learning, large classes in higher education is a term that has no universally accepted definition; some institutions use the term “large” to refer to classes of more than forty students (Cuseo, 2007), while other institutions regard a large class as one with more than 200 students (Saunders & Gale, 2012).

Challenges and Opportunities of Large Classes

Teaching large classes has its own dynamics for faculty and presents significant challenges in teaching. Many researchers (Cole & Spence, 2012; Lindlaub, 1981; McKagan et al., 2007; Mora et al., 2012; Saunders & Gale, 2012) agree that faculty members who teach them describe large classes as a more demanding context for teaching than smaller classes because they require more effort and much greater attention to organization and management. Holding students’ attention in an auditorium is more difficult than in a classroom of 30 students because they are physically distant from the professor. Many aspects of the course must be carefully organized, even scripted, because simple mistakes in lectures, assignments, or exams may confuse hundreds of students, not just a few. Large classes may also require a level of personnel management and supervision (McKagan et al., 2007; Mora et al., 2012) that can be extremely time-consuming. Because many instructors of large classes rely heavily on graduate teaching assistants to lead discussion sections and evaluate students' exams and papers, often faculty members must carefully supervise and assist the teaching assistants, in addition to working with the undergraduates.

For students, large classes offer a different set of challenges. Some students feel anonymous (Cole & Spence, 2012) in large classes because they rarely know many of the other students (if any) and the faculty member rarely gets to know them as individuals. Students find this anonymity impersonal and off-putting (Cole & Spence, 2012), particularly students who are used to a smaller and supervised learning environment. Unfortunately the impersonal quality of large classes is sometimes coupled with limited access to instructional assistance. With very large numbers of students, faculty members and teaching assistants have very limited time to devote to any one individual. As a result, students must learn more independently, relying less heavily on interaction with the instructor and more heavily on their own abilities and interactions with teaching assistants and peers (McKagan et al., 2007).

Despite these challenges, large classes may provide faculty members and students with unique opportunities for teaching and learning. Given their size, large classes often include a more diverse group of students (Cooper & Robinson, 2000; Wilson & Tauxe, 1986). Diversity enlivens conversations and discussions, and makes for more interesting learning. Equally gratifying is the faculty member's sense of wide educational impact in large classes where ideas and materials are studied and learned by many students from very different educational backgrounds and perspectives (Brewer & Zabinski, 1999). Finally, working with teaching assistants in large classes is often quite rewarding. Many faculty members believe that there is little that they do which is more important than training the next generation of professors how to teach effectively (McKagan et al., 2007). Large classes provide a valuable context for this training.

Many undergraduates thrive on large classes for precisely the same reasons that others dislike them. Some large classes offer a low-pressure context for learning and an opportunity to exercise independence in deciding what and how to learn (Cooper & Robinson, 2000). Large classes offer greater flexibility in class participation and attendance than small classes (McKagan et al., 2007). Some students may find this attractive because it enables them to coordinate more effectively their academic and work schedules. Finally, large classes offer nearly limitless opportunities for making contacts with other students, either to study or just to meet.

Learning Theories

Learning theories cannot be divorced from effectiveness of student learning and acts as a general explanation for observations made over time in order to address the challenges of helping learners succeed and to explain and predict behavior (Fulop & Chater, 2004; Harasim, 2011; Sandlin, Wright, & Clark, 2013; Sigette, 2009; Thurlings, Vermeulen, Bastiaens, 2013; Wu, Hsiao, & Wu, 2012). To understand the complex process of learning, in essence, the theory about human learning can be categorized into six broad paradigms: behaviorism, cognitivism, constructivism, experiential, humanistic, and social-situational learning theories (Schunk, 2011).

Behaviorism is a theory, which concerns the observable change in behavior (Moore, 2011). Behaviorists believe that learning is provided by change in actions through an explorative process (Faryadi, 2007). Behaviorism exposes individuals to external stimuli until a desired response is received. In this theory, knowledge is transferred by the teacher while the learner is a passive participant. *Cognitivism* emerged when researchers found out that behaviorism did not account for all types of learning (Jackson, 2003). According to this theory, knowledge can be viewed as a scheme, that is, symbolic mental constructions that are organized or processed in the mind (Sawyer, 2012). Learning occurs when there is a change in the learner's schemata; the learner is an active participant (Watson & Coulter, 2008). On the other hand, *constructivism* assumes that learning is a process of constructing knowledge rather than acquiring it (Martell, 2012). It takes the learner's social, cultural and contextual conditions into consideration and theorizes that the learner constructs knowledge through experience (Gopnik & Wellman, 2012). In other words, learners interpret new information through their contextual experiences and build on their existing knowledge from the conclusions reached during the assimilation of new knowledge and reflection on it (Savasci & Berlin, 2012). *Experiential learning theory* is a holistic perspective on learning that combines experiences, perception, cognition and behavior (Calpito, 2012; Leavitt, 2011). The theory emphasizes the central role of experience in the learning process (Barber, 2012; Jordi, 2011; Sandlin et al., 2013). It is a continuous process grounded in experience. *Humanistic* is another theory of learning and priorities for human needs and interests (Lin, Chien, & Jarvie, 2012). This theory believes that it is necessary to study the person as a whole, especially as an individual grows and develops over the lifespan (Dollarhide, 2012). Finally, *socio-situational* theorists emphasize that learning takes place in social relationships (Smith, 1999; Yuan & McKelvey, 2004). Social learning theory posits that people learn from observing other people.

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 (Faleye, 2011; Kelley & Kellam, 2009; Stier & Laigen, 2010; Zascerinska, 2010). Out of the six paradigms, researchers (Kazakci, 2013; Kelley & Kellam, 2009; Stier & Laigen, 2010) believe constructivism aligns best with engineering education. It is a theory of learning founded on the premise that the reflection of our experiences will construct our own understanding of future knowledge, much like the purposeful, deliberate, and systematic nature of engineering, which requires reflection on past knowledge to construct future creations. There are several guiding principles of constructivism (Gopnik & Wellman, 2012; Kelley & Kellam, 2009; Martell, 2012; Savasci & Berlin, 2012; Stier & Laigen, 2010):

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

Elements of Effective Teaching and Learning Using Student-Centered Pedagogy in Large Classes

Although there is no single, best method for addressing the effectiveness of student learning, especially in large classes, at least seven elements of effective teaching, suggested by numerous researchers discussed below, shape how much and how well students learn in this context.

The *first* is careful design and preparation of the course (Zorn & Kumler, 2003). Course design shapes students experiences, the pathways through areas of content and the mechanism by which material is learned. In the absence of careful design and adequate preparation, students may have great difficulty following the flow of material and course work. This problem is magnified in large courses because a greater number of students is more likely to become confused, particularly since they have limited access to the instructor for individualized assistance in explaining difficult material or in clarifying the relationships between different parts of the course (Adrian, 2010).

A *second* important element to effective leaning in large classes is the quality of the instructor's presentations to students (Al Nashash, 2013). Whether these are formal lectures, facilitated exercises or laboratories, or interactive conversations, the preparation and delivery of the presentations is critical to students' perceptions and grasp of the content of the course. Large classes typically rely heavily on some form of lecture or presentation (Yazedjian & Kolkhorst, 2007). Separate from other parts of the class, these presentations can either "make or break" learning for hundreds of students. The level of enthusiasm the instructor communicates for the material and the clarity of ideas the instructor delivers will influence whether many students engage the ideas and commit to working hard over the course of the term in studying and learning (Fata, 2011; Kryder, 2002).

A *third* aspect of large courses that effects how well students learn is the level of administration and management of the course (Cakmak, 2009). Large courses present a host of unique administrative challenges that range from ensuring continuity among discussion sections led by different teaching assistants to those associated with distributing and collecting students' examinations in a large lecture hall in a timely manner. The challenges are not trivial; they certainly influence how well students perform on many aspects of the course (Hejmadi, 2007), and when they go wrong are often the subject of students' vocal complaints. More students will learn the material if the course is well organized and well managed.

Fourth, classes that incorporate some form of active or experiential learning engage students more effectively than classes that do not (Mulryan-Kyne, 2010). The traditional "lecturing/listening" model of teaching is typically less effective because students play a primarily passive role, taking little responsibility for making sense of the content or in applying it to the solution of problems (Gleason, 1986). Obviously, the challenge in large courses is finding mechanisms by which learning can be active and participatory. Traditional interactive exchanges between the instructor and students that may work well in seminars and small classes can rarely be used in classes of much over forty students. In large classes, students may participate in the learning process with one another or in experiences altogether outside of the classroom. In these types of experiences, the professor's role shifts from lecturer to facilitator, from expositor to coordinator (Mulryan-Kyne, 2010). Collaborative working groups among students, small group discussions in the lecture hall, and experiential learning opportunities remove the students from the role of passive learner, putting him or her in a participatory role (Thomas et al., 2011).

An increasingly important *fifth* element of large classes is engaging students through the use of multimedia. For decades instructors have relied on films, photographic images, and transparencies to convey ideas or to offer illustrations (Frost & Pierson, 1998). These are particularly important to teaching and to learning in large classes because of the diversity of student experiences and learning preferences. They offer students different "looks" at the material and, at the same time, provide the instructor with pedagogical stimuli that are likely to engage students, particularly those who are visually oriented (Moravec, Williams, & Aguilar-Roca, 2010; Rowland-Bryant, Skinner, & Dixon, 2011; Walker, Cotner, & Beermann, 2011).

Ensuring that graduate student teaching assistants are adequately prepared and supervised is a *sixth* element of effective teaching in large classes (Ghosh, 1999; Rieber, 2004; Sargent, Allen, & Frahm, 2009). Although instructors use teaching assistants differently, many large courses are divided into lecture and recitation sections, with teaching assistants taking instructional responsibility for the latter. The obvious challenge is that most graduate students have little teaching knowledge and experience. Further, they may have little or no knowledge of the content of the course. Because teaching assistants often spend more time with students individually and in smaller groups than the instructor in a large class, they must receive adequate preparation in course content and in how the material must be taught (Goodman, Koster, & Redinius, 2005).

A *final* element related to how well faculty teach and how well students learn is assessment (Wanous, Procter, & Murshid, 2009). To what extent does the instructor incorporate assessment into his/her analysis of the course and student learning? At the heart of this issue is the idea that affective teaching must be informed with knowledge about what students learn and how they learn (Hancock, 2010; Harris, 2011; Schultz, 2011; Winstone & Millward, 2012). In large classes this is particularly challenging because there are few ready mechanisms other than examinations and assignments, for assessing whether students grasp the material or are engaged in the subject. Although exams do shed light on levels of student learning, they are not necessarily informative about the problems students may experience in the course or the precise causes of their problems. Traditional exams and assignments do not necessarily reveal whether the instructor and teaching assistants offer perspectives on the course material that are consistent or complimentary (Hancock, 2010). They also do not necessarily reveal whether poor student performance is the result of inadequate preparation by the students or insufficient clarity on the part on the instructor, such as in his/her presentations, assignments, and material (Wanous et al., 2009). Finally, the information that traditional examinations provide is often not timely because the exams are retrospective, shedding light on work and material in weeks past rather than in the present. The most effective assessment centers on levels of student learning (Harris, 2011). To the extent that assessment is routine and continuous throughout a course (not simply at the end of the term), it will prove most useful to solving students' leaning difficulties or problems (Wanous et al., 2009). Immediately knowing that problems exist in a course enables the instructor to respond to difficulties "as they arise". However, this approach to assessment implies high levels of student participation in the course. For example, students must routinely comment on or evaluate presentations, assist in the development and analysis of examinations and assignments, or participate collaboratively with the instructors and teaching assistants in the teaching and learning material. The course becomes somewhat versatile, always changing in character and form in response to problems and issues in student learning that arise over the course of the term. The difficulty, of course, is that large classes, heavy student participation can be enormously burdensome for the instructor, given the obvious logistical challenges (Winstone & Millward, 2012).

Role of Class Size in Effective Teaching and Learning Using Student-Centered Pedagogy

One of the main criticisms of large classes is that student learning is passive and shallow (Adrian, 2010). Faculty lecture and students take notes without much interaction or exchange; material is learned for exams and then quickly forgotten at the end of the term. Because deep learning is more likely to occur when students repeatedly interact with the material and instructor, many faculty members seek strategies for incorporating more active learning into large classes (Kryder, 2002).

Although many researchers (Al Nashash, 2013; Cakmak, 2009; Fata-Hartley, 2011; Kryder, 2002; Yazedjian & Kolkhorst, 2007) have creatively suggested active learning inside the classroom, but as class size increases, most instructors indicate that the level of participation decreases. Too often class size dictates the procedures used to transmit knowledge to students. Recent research and experimentation (Adrian, 2010) suggest that active learning can function in both large and small classrooms. A recent collection of articles dedicated to active learning (Al Nashash, 2013; Cakmak, 2009; Fata-Hartley, 2011; Kryder, 2002; Yazedjian & Kolkhorst, 2007) suggests that class size make little difference in the success or failure of active learning. Small classes are not necessarily needed for meaningful learning experiences.

Methods

Data Analysis

This study employed a descriptive and correlational research design to understand the outcome of student learning effectiveness concerning the impact of learning intervention on their academic learning and to investigate the influence of these factors on student academic success. Quantitative data collection was employed which allowed the data to be quantified and analyzed using statistical analyses. 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 analysis and all results were presented in aggregate form such that no individuals can be identified. This ensured that the investigators in this project cannot identify the individuals to whom the data pertain.

Population

The population of this study was engineering students enrolled at Iowa State University. Iowa State University, located in Ames, Iowa, 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 was students enrolled in statics of engineering (EM 274) classes from fall 2006 until spring 2013 and students enrolled in mechanics of materials (EM 324) classes from spring 2007 until spring 2013. Demographic characteristics in this study included a total of 4937 students, 4282 (86.7%) males and 655 (13.3%) females, over a span of 7 years, from 2006 to 2013.

Procedure

This study aimed to answer the overarching question of whether there is a difference in student performance in a large IFEM classes between the traditional, 50-minute, three times a week class (passive, teacher-centered learning) and an experimental pedagogy, 50-minute, three times a week class which involved interventions including supplemental videos and interactive-teaching style (active, student-centered learning). A comparison was designed to focus on two areas of progress: 1) do active learning pedagogies effect student performance in statics of engineering and 2) does performance in statics of engineering predict performance in mechanics of materials.

Passive learning featured the typical lecture format where the instructor speaks at the front of the room and the class sits facing the instructor. Interaction between the teacher 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, implied by its very title something “other than” the traditional lecture format. The concept of active learning is simple: rather than the faculty presenting facts to the students, the students play an active role in learning by exploring issues and ideas under the guidance of the faculty. Instead of memorizing, and being mesmerized by a set of often loosely connected facts, the student learned a way of thinking, asking questions, searching for answers, and interpreting observations.

For the first area of progress (research questions 1 and 2) in this research, a cross sectional, ex-post facto study was carried out on two groups of participants: 1) undergraduate students at Iowa State University who were enrolled in the traditional statics of engineering class, and 2) undergraduate students at Iowa State University who were enrolled in an experimental pedagogy statics of engineering class.

Continuity of understanding from one fundamental engineering concept to the next was analyzed in the second area of study (research question 3) by measuring progress of overall class performance in statics of engineering with overall class performance in mechanics of materials, which is the next class in the sequence of IFEM courses for most engineering disciplines.

Limitations of the Study

The principal objective of this study was to investigate and evaluate outcomes of the experimental pedagogy class in terms of student understanding and data collected from semesters fall 2006 until spring 2013. Any known difference between fall and spring semester's cohorts was not considered as a potential confounding variable in this study.

There may be a limited generalizability and a potential for bias from the future findings due to the absence of a randomization of the selected sample participants, due to the fact 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. Thus, caution should be exercised when generalizing the findings of this study to other populations.

Definitions of Terms

1. *Large classes* to refers to classes of more than forty students (Cuseo, 2007).
2. *Passive learning* refers to the typical lecture format where the instructor speaks at the front of the room and the class sits facing the instructor. Interaction between the teacher and students often appeared stiff and limited to questions and answers. The typical lecture format limited interaction among students during class time.
3. *Active learning* refers to something "other than" the traditional lecture format. The concept of active learning is simple: rather than the teacher presenting facts to the students, the students play an active role in learning by exploring issues and ideas under the guidance of the instructor. Instead of memorizing, and being mesmerized by a set of often loosely connected facts, the student learned a way of thinking, asking questions, searching for answers, and interpreting observations.

Dissertation Organization

This dissertation is comprised of five chapters.

Chapter 1 addresses the problem, purpose, research questions, significance and assumptions of the study. The chapter also consists of reviews literature on definition of large classes, challenges and opportunities of large classes, learning theories, elements of effective teaching and learning using student-centered pedagogy in large classes, and roles of class size in effective teaching and learning using student-centered pedagogy. It then outlines the methods of the study describing research design, procedures, and data analysis.

Chapter 2 answers the first research question of *do active learning pedagogies in large classes improve student ability to understand course concepts and learn problem-solving* *measured through semester examination scores, homework scores, and final class grades*? This chapter is formatted as a manuscript for the ASEAN Journal of Engineering Education.

Chapter 3 answers the second research question of *do constructivist pedagogies using different levels of interventions improve student performance measured through comparisons of final class grades of different cohorts taught by a single faculty member*? This chapter is formatted as a manuscript for the Journal of Engineering Education.

Chapter 4 answers the third research question of *do scaffolding and cooperative learning improve student ability in the next class in the same sequence?* This chapter is formatted as a manuscript for the Journal of STEM Education.

Chapter 5 includes a summary of the research, describes conclusions, and provides direction for future research and practical implications.

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CHAPTER 2. EXPLORING ACTIVE LEARNING IN INTRODUCTORY, FUNDAMENTAL ENGINEERING MECHANICS STATICS CLASS

A paper submitted to the ASEAN Journal of Engineering Education

Peggy Boylan-Ashraf, Steven A. Freeman, Mack C. Shelley

Abstract

This study investigated the role of a new paradigm in teaching large introductory, fundamental engineering mechanics (IFEM) courses that combined student-centered learning pedagogies and supplemental learning resources. Demographic characteristics in this study included a total of 405 students, of whom 347 (85.7%) are males and 58 are (14.3%) females. The students' majors included aerospace engineering, agricultural engineering, civil engineering, construction engineering, industrial engineering, materials engineering, and mechanical engineering.

Results of this study, as tested using an independent samples *t*-test and validated using a nonparametric independent samples test and a general linear multivariate model analysis, indicated overwhelmingly that there is a difference between a class taught passively using the teacher-centered pedagogy and a class taught actively using student-centered pedagogy.

The principal focus of this work was to determine if the new paradigm was successful in improving student understanding of course concepts in statics of engineering using student-centered pedagogies in large classes. 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 academic reform but hesitant to abandon conventional teaching practices. By promoting a new paradigm, the potential for improving understanding of engineering fundamentals on a larger scale may be realized.

Keywords: *Active Learning, Statics of Engineering, Large Classes.*

Introduction

IFEM courses, which include statics of engineering, mechanics of materials, dynamics, and mechanics of fluids are essential components to many engineering disciplines (Steif & Dollar, 2008). This study is an evaluation of a new paradigm incorporating a pedagogical reform that was performed over two semesters at Iowa State University (ISU) in its College of Engineering. The focus of the new paradigm was using student-centered learning to promote better understanding of conceptual fundamental knowledge for students.

Student-centered learning was first introduced as early as the 1960s under a reform pedagogy called guided inquiry (Karplus & Their, 1969). It was introduced in 3 phases: an exploration phase, an invention phase, and an application phase. This pedagogy has been found to provide students with a significantly better conceptual understanding compared to students taught traditionally (Barman, Barman, & Miller, 1996; Marek, Cowan, & Cavallo, 1994; Stephans, Dyche, & Beiswenger, 1988).

Traditionally taught students are understood as those whose instruction primarily focuses on verbal and printed words, rote memorization, and is instruction driven (Schneider & Renner, 1980). Students who are taught traditionally are told what they are expected to know and concepts are presented deductively, where the faculty conducts lessons by introducing and explaining concepts to students, and then expecting students to complete tasks to practice the concepts. Modern interpretations of student-centered learning include project-based learning, case-based learning, discovery learning, and just-in-time teaching with 3 instructional approaches of active learning, cooperative learning, and problem-based learning (Prince & Felder, 2004).

With the hope of effectively investigating the most fruitful way to teach IFEM courses in large lectures, and to compare the *traditional pedagogy*, which is the full 50-minute lecture, three times a week class to an *experimental pedagogy*, which is the 50-minute, three times a week class centered on active learning, this quantitative study was designed to explore variables affecting student academic success. The variables included demographic characteristics and grades earned in class, including examinations grades, homework grades, and final class grades. This study was conducted using data from 2 semesters in statics of engineering (EM 274) at ISU from 2 different faculty members teaching 2 different sections, one using the traditional-style pedagogy and the other using an experimental pedagogy.

Statics of engineering was chosen because its concepts and applications are needed in almost every discipline of engineering (Benson et al., 2010; Rutz et al., 2003). It is a fundamental prerequisite for subsequent courses such as mechanics of materials, dynamics, and mechanics of fluids, and in some programs, other courses such as tool design, etc. (Beer & Johnston, 2004; Orr, Benson, & Biggers, 2008). Many researchers (Beer & Johnston, 2004; Orr et al., 2008; Rutz et al., 2003) believe that performance in these later courses can be directly correlated to success in statics of engineering.

In the past statics of engineering has often been taught in a traditional lecture and note-taking approach. According to current understanding (Thomas, Subramaniam, Abraham, Too, & Beh, 2011; Zorn & Kumler, 2003), humans think, learn, and solve problems by making connections and associations to previous experiences. Numerous researchers (Gleason, 1986; Thomas et al., 2011; Zorn & Kumler, 2003) have written that if one's first exposure to fundamental concepts takes place by passively hearing it in lecture or by reading it in a textbook, the experience may not be sufficiently significant or rich to build connections. Thus, determining factors that could facilitate academic success in statics of engineering should be a major concern in engineering education.

Literature Review

Introduction of Literature

As seen from decades of scholarly work about student-centered learning in engineering, there seems to be some validity to the claim that engineering colleges are "slow to change" (Basken, 2009). Also, it appears to be unproductive to expect education change to occur immediately at any macro-level, either governmental or institutional. This leads to the conclusion that expectations for educational change should focus on change at the micro-level within specific settings where teaching and learning is occurring—the classroom. Now the questions become, what type of micro-level changes should occur, particularly in IFEM courses, such as statics of engineering, mechanics of materials, dynamics, and mechanics of fluids; and what should be the goals of this change?

A review of the literature supports the idea that the climate of the education setting in teaching IFEM courses should change from instructor-controlled, passive learning to an environment that encourages mutually controlled, active learning (Abdulaal, Al-Bahi, Soliman, &Iskanderani, 2011; Hsieh & Knight, 2008; Kotru, Burkett, & Jackson, 2010; Myllymaki, 2012). Also supported in the literature is the statement that the goal of teaching any introductory, fundamental courses of any discipline should be to improve learners' fundamental concepts of the respective discipline and their critical thinking skills (Ahern, 2010; Pierce, 2013). Scholars active in this field (Abdulaal et al., 2011; Vallim, Farines, & Cury, 2006) believe that active learning cannot and should not be taken out of the process of teaching. For the purpose of this article, the authors define active learning as a classroom ethos in which students are responsible not only for their own learning but also for that of their peers.

Most would agree that from a practical perspective, everyday life involves being able to function successfully, actively, and cooperatively in groups, not only in the work place, but also within the family unit. This concept also gives an important educational justification as studied by Magno (2010), which showed that successful actively and cooperatively engaged thinkers have strong metacognitive abilities—they know what they know and do not know, can plan a strategy, are conscious of the steps taken, and can reflect on and evaluate their thinking.

In general, student learning can be broadly categorized into two groups of pedagogies—the traditional *teacher-centered pedagogy* and the *student-centered pedagogy* (Huba & Freed, 2000). According to Huba and Freed (2000), the teacher-centered pedagogy involves knowledge transmission from faculty to students, who passively receive information. They assert that in a teacher-centered environment assessments are used to monitor learning with an emphasis on the right answer and the learning culture is competitive and individualistic. These features are contrasted by the student-centered pedagogy that actively involves students in constructing knowledge. Many researchers (Abdulaal et al., 2011; Hsieh & Knight, 2008; Kotru et al., 2010; Myllymaki, 2012) agree with Huba and Freed (2000) that the student-centered method emphasizes generation of better questions, learning from errors, and assessments that are used to diagnose and promote learning. All of these researchers above argue that the learning culture should be active, cooperative, collaborative and supportive, wherein both the faculty members and students learn.

Active Learning

Proponents of teacher-centered pedagogy (Detlor, Booker, Serenko, & Julien, 2012; Drew & Mackie, 2011; Kim, Sharma, Land, & Furlong, 2013; Leng, Xu, & Qi, 2013; Rahmat & Aziz, 2012; Scott, 2011; Stephen, Ellis, & Martlew, 2010) argue that the usual lecture method as seen in the majority of engineering classrooms would be more effective when used along with other teaching strategies. Students will remember more if brief activities are introduced to the lecture and they are "actively" performing something other than just listening (Prince & Felder, 2004). Several researchers (Hsieh & Knight, 2008; Laws, Sokoloff, & Thornton, 1999), who incorporated active learning strategies in their instruction, have shown significant positive effects on student learning and perception. These researchers argue that the term "active learning", as the term suggests, should be defined as an instruction method or a learning experience, which is "active" in nature. Either physical or cognitive action can keep students and faculty engaged with both becoming active participants in the learning process. The term "participants" is very crucial in describing active learning because both the students and the instructor "participate", hence learning from the experience (Rahmat & Aziz, 2012). Both are "active" and the explicit intent of active learning methods is not only to improve the learning of students, but also the development of the faculty member as he/she refines his/her strategies in the teaching-learning process. A working definition for active learning in a college classroom is proposed as a learning method that "involves students in doing things and thinking about the things they are doing" (Bonwell & Eison, 1991).

Bonwell and Eison (1991) listed some general characteristics associated with active learning strategies in a classroom: students are involved in more than listening; less emphasis is placed on transmitting information and more on developing students' skills; students are involved in higher-order thinking (e.g., analysis, synthesis, evaluation); students are engaged in activities (e.g., reading, discussing, writing, etc.); and greater emphasis is placed on students' exploration of their own attitudes and values.

Carmean and Haefner (2002) developed a core set of *Deeper Learning Principles*, which is an engaged learning that results in a meaningful understanding of material and content. The Deeper Learning Principles include learning that is social, active, contextual, engaging and student-owned. Along with these principles there is also a need to emphasize the importance of long-term memory and learning based on building enduring conceptual structures (Detlor et al., 2012; Drew & Mackie, 2011; Foreman, 2003; Kim et al., 2013; Leng et al., 2013; Rahmat & Aziz, 2012; Scott, 2011; Stephen et al., 2010).

The one underlying emphasis that can sum up these views on active learning is that the real understanding of concepts can be revealed in the ability of the learner to apply the concepts that they have learned in different situations (Rahmat & Aziz, 2012). Not just factual information recall, but a more applied use of the gained factual knowledge, can be credited to an effective learning experience.

Issues of Active Learning

In the review of emerging issues in student-centered pedagogies some researchers (e.g., Bonwell & Eison, 1991) have listed several reasons for the hesitation in adopting active learning techniques in college classrooms, such as faculty evaluation by students and the administration, classroom environments, assessments in both institutional and class level, and the need for more supporting resources. Bonwell and Eison (1991) highlighted 5 important barriers in adopting active learning strategies, which include inability to cover content, time required to prepare for classes, inability to use it in large classes, lack of materials and resources, and the risk of evaluation by students and peer instructors.

Since transfer of information in a one-way path from faculty member to student is less time consuming compared to a two-way or rather multi-way path of discussions and questions, a common criticism of the student-centered instructional model, as indicated by Bonwell and Eison (1991), is its inherent tendency to take more time than a traditional lecture model to cover the same content. The need to spend more time in preparing and delivering an active learning method of instruction can inhibit faculty from trying and testing its benefits. For a higher-quality faculty professional development, more research needs to be done in this subject of implementing active learning (Slavin, 1991). So, one of the main challenges of this study is to devise an active learning strategy that not only enhances the experience and effectiveness but also remains within the same time period as a regular lecture format—How can active learning concepts be incorporated in IFEM courses, such as statics of engineering, mechanics of materials, dynamics, and mechanics of fluids curriculum to enhance the teaching and learning experience of the faculty and the students without a huge shift from the traditional methods of instruction? This article attempts to answer that question.

Active Learning in Large Lectures and the Role of Class Size

Although there is no single, best method for addressing the effectiveness of student learning, especially in large classes, at least seven elements of effective teaching, suggested by numerous researchers discussed below, shape how much and how well students learn in this context:

1. Careful design and preparation of the course (Zorn & Kumler, 2003)
2. The quality of the instructor's presentations to students (Al Nashash, 2013)

3. The level of administration and management of the course (Cakmak, 2009)
4. Implementing some form of active or experiential learning, which will engage students more effectively (Myllymaki, 2012)
5. Use of multimedia (Rowland-Bryant, Skinner, & Dixon, 2011; Walker, Cotner, & Beermann, 2011)
6. Adequate preparation of graduate student teaching assistants to aid in the classroom (Sargent, Allen, & Frahm, 2009)
7. The level of managing assessments (Wanous, Procter, & Murshid, 2009)

Although many researchers (Al Nashash, 2013; Cakmak, 2009; Fata-Hartley, 2011; Yazedjian & Kolkhorst, 2007) have creatively suggested ways to achieve active learning inside the classroom, but as class size increases most faculty indicate that the level of participation decreases. Too often class size dictates the procedures used to transmit knowledge to students. Recent research and experimentation (Ahern, 2010) suggest that active learning can function in both large and small classrooms. A recent collection of articles dedicated to active learning (Al Nashash, 2013; Cakmak, 2009; Fata-Hartley, 2011; Yazedjian & Kolkhorst, 2007) suggests that class size makes little difference in the success or failure of active learning. Small classes are not necessarily needed for meaningful learning experiences.

Summary of Literature

Research has shown across the board the effects of active learning are positive and robust. When compared to implementation strategies suggested in the literature the active learning model appears to be a strong model for fostering the development of students' understanding of fundamental engineering concepts in large classes, such of statics of engineering, mechanics of materials, dynamics, and mechanics of fluids. If implementing an active learning model does improve the growth of students' engineering fundamental knowledge, the case for active learning in large classes as a way to implement micro-level educational change becomes even stronger in the first and second-year engineering curriculum.

Research Question

This study sought to answer the question, *do active learning pedagogies in large classes improve student ability to understand course concepts and learn problem-solving measured through semester examination scores, homework scores, and final class grades?*

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 (ISU website, 2013). The population from which the respondents were drawn are students enrolled in statics of engineering (EM 274) classes in fall 2012 and spring 2013. The sample consisted of a total of 405 students, of whom 347 (85.7%) are males and 58 (14.3%) are females. The students' major include the typical majors required to take statics of engineering in an engineering college: aerospace engineering, 74 students (18.3%); agricultural engineering, 8 students (2.0%); civil engineering, 62 students (15.3%); construction engineering, 14 students (3.5%); industrial engineering, 24 students (5.9%); materials engineering, 33 students (8.1%); and mechanical engineering, 169 students (41.7%). There were 21 students (5.2%) who were from outside the majors mentioned above.

Design and Procedure

This study aimed to answer the overarching question of whether there is a difference in student performance in an IFEM class of statics of engineering between the *traditional*, teacher-centered pedagogy, 50-minute, three times a week class (passive learning) and an *experimental*, student-centered pedagogy, 50-minute, three times a week class, which involved interventions including supplemental videos and interactive-teaching style (active learning). A comparison was designed to focus on three areas of progress, which were student examination scores, student homework scores, and student overall class performance.

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

Active learning, on the other hand, 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 play an active role in learning by exploring issues and ideas under the guidance of the instructor. Instead of memorizing, and being mesmerized by a set of often loosely connected facts, the students learn a way of thinking, asking questions, searching for answers, and interpreting observations.

In this research, a cross sectional, ex-post facto study was carried out on two groups of participants during two different semesters: 1) undergraduate students at ISU who were enrolled in the *traditional statics of engineering class* during two different semesters, fall 2012 and spring 2013, and 2) undergraduate students at ISU who were enrolled in an *experimental pedagogy statics of engineering class* during the same two semesters, fall 2012 and spring 2013.

Independent Variable

The independent variable used in this study is *type of class*—traditional, passive learning class versus experimental, active learning class. The traditional class was a 50-minute, three times a week class, passive pedagogy, teacher-centered learning approach. The experimental class was a 50-minute, three times a week class, active pedagogy, student-centered learning approach. The experimentally taught class involved interventions including supplemental videos and interactive teaching style, which involved think-pair-share, one-minute muddiest point, and problem solving in groups.

Dependent Variables

The dependent variables used in this study are *exam 1 scores, exam 2 scores, exam 3 scores, final exam scores, homework scores, and final class grades*. Exam 1 was an evaluation on topics, which included: introduction to statics, force systems, rectangular versus non-rectangular components, two- and three-dimensional moments, couples, and two- and three-dimensional resultants. Exam 2 was an evaluation on topics, which included: free-body diagrams, two- and three-dimensional equilibrium, frames and machines, trusses, center of mass and centroid, and distributed loads. Exam 3 was an evaluation on topics, which included: beams, friction, second moment of area, product of inertia, and mass moments of inertia. The final exam was an evaluation on the comprehensive topics covered from the beginning of the semester until the end. Three homework problems were assigned for each lecture.

The database of the students' class performance in this study was obtained from individual instructors' databases. One of the authors of this study taught the experimental, student-centered pedagogy, active learning class. Another faculty member taught the traditional, teacher-centered pedagogy, passive learning class. Both instructors used identical methods in calculating students' final class grades, as described in the class syllabus. The class syllabus was distributed to each student on the first day of class and posted on Blackboard Learn throughout the entire semester for student access.

Data Analysis

This study employed an independent samples *t*-test, a nonparametric independent samples test, and a general linear multivariate model analysis to understand the outcome of student learning effectiveness concerning the impact of learning interventions using student-centered pedagogy on their academic learning. With the hope of effectively investigating the most fruitful way to teach IFEM courses in large lectures, this study aimed to answer the overarching question of whether there is a difference in student performance in a large lecture IFEM class of statics of engineering between the traditional 50-minute, three times a week class (passive, teacher-centered learning pedagogy) and an experimental pedagogy, 50-minute, three times a week class, which involved interventions including supplemental videos and interactive-teaching style (active, student-centered learning pedagogy). 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 any 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.

Results and Discussion

Before performing any analysis, histograms of the dependent variables were examined to confirm normality. Normality assumptions were not met; thus the independent samples *t*-test was validated with a nonparametric independent samples test, and also with a general linear multivariate model analysis. A summary of descriptive statistics (*N*, *M*, and *SD*) of each dependent variable by class type is seen in Table 1. Results, as summarized in Table 1, show that the experimental class (active, student-centered learning pedagogy) has means greater than those of the traditional class (passive, teacher-centered learning pedagogy) in every dependent variable, except for homework grades; and the standard deviations of the experimental class (active, student-centered learning pedagogy) are less than that of the traditional class (passive, teacher-centered learning pedagogy) in every dependent variable.

Table 1

Descriptive Statistics of Dependent Variables

	class type	*N*	*M*	*SD*
exam 1	experimental	108	89.45	10.80
	traditional	297	81.60	13.53
exam 2	experimental	108	86.22	12.37
	traditional	297	70.52	18.20
exam 3	experimental	108	90.49	10.36
	traditional	297	81.72	16.53
final exam	experimental	108	87.71	11.39
	traditional	297	61.28	14.18
homework	experimental	108	77.64	21.10
	traditional	297	84.99	25.10
final class grade	experimental	108	91.69	7.48
	traditional	297	74.99	14.18

An independent samples *t*-test was conducted to determine if there were statistically significant differences in student performance, as measured from exam 1 scores, exam 2 scores, exam 3 scores, final exam scores, homework scores, and class grades between students taught using the active, student-centered approach and students taught using the passive, teacher-centered approach. Results, as summarized in Table 2, show that:

1. There is a *statistically significant difference* in the scores of *exam 1* for the experimental,

active, student-centered class (*M*=89.45, *SD*=10.80) and for the traditional, passive, teacher-centered class (*M*=81.60, *SD*=13.53); $t(236.288)=6.032$, $p < .001$.

2. There is a *statistically significant difference* in the scores of *exam 2* for the experimental, active, student-centered class (*M*=86.22, *SD*=12.37) and for the traditional, passive, teacher-centered class (*M*=70.52, *SD*=18.20); $t(279.232)=9.868$, $p < .001$.

3. There is a *statistically significant difference* in the scores of *exam 3* for the experimental, active, student-centered class (*M*=90.49, *SD*=10.36) and for the traditional, passive, teacher-centered class (*M*=81.72, *SD*=16.53); $t(302.913)=6.336$, $p < .001$.

4. There is a *statistically significant difference* in the scores of *final exam* for the experimental, active, student-centered class (*M*=87.71, *SD*=11.39) and for the traditional, passive, teacher-centered class (*M*=61.28, *SD*=14.18); $t(403)=17.436$, $p < .001$.

5. There is a *statistically significant difference* in the scores of *class grade* for the experimental, active, student-centered class (*M*=91.69, *SD*=7.481) and for the traditional, passive, teacher-centered class (*M*=74.99, *SD*=14.18); $t(351.947)=15.278$, $p < .001$.

These results suggest that active, student-centered pedagogy does have an effect on student performance.

Table 2

Independent Samples t-Test

		Levene's Test for Equality of Variances		*t*-test for Equality of Means						
		F	*Sig.*	*t*	*df*	*p* (2-tailed)	Mean Difference	Std. Error of Difference	95% Confidence Interval of the Difference	
									Lower	Upper
exam 1	equal variances assumed	6.033	.014	5.435	403	.000	7.854	1.445	5.013	10.695
	equal variances not assumed			6.032	236.288	.000	7.854	1.302	5.289	10.419
exam 2	equal variances assumed	16.017	.000	8.293	403	.000	15.700	1.893	11.979	19.422
	equal variances not assumed			9.868	279.232	.000	15.700	1.591	12.568	18.832
exam 3	equal variances assumed	3.953	.047	5.153	403	.000	8.767	1.701	5.422	12.111
	equal variances not assumed			6.336	302.913	.000	8.767	1.384	6.044	11.489
final exam	equal variances assumed	.543	.462	17.436	403	.000	26.4255	1.5156	23.4460	29.4050
	equal variances not assumed			19.288	234.535	.000	26.4255	1.3700	23.7264	29.1246
home work	equal variances assumed	.730	.393	-2.715	403	.007	-7.354	2.709	-12.679	-2.030
	equal variances not assumed			-2.943	224.005	.004	-7.354	2.499	-12.279	-2.430
final grade	equal variances assumed	8.926	.003	11.660	403	.000	16.701	1.432	13.885	19.517
	equal variances not assumed			15.278	351.947	.000	16.701	1.093	14.551	18.851

Next, the independent samples *t*-test was validated using a nonparametric independent samples test, as shown in Figure 1. Again results, as summarized in Figure 1, show that indeed there are overwhelmingly significant differences in student performance as measured through exams scores and final class grades.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Exam1 is the same across categories of ClassType.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.
2	The distribution of Exam2 is the same across categories of ClassType.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.
3	The distribution of Exam3 is the same across categories of ClassType.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.
4	The distribution of Final is the same across categories of ClassType.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.
5	The distribution of HW is the same across categories of ClassType.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.
6	The distribution of Grade is the same across categories of ClassType.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.

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

Figure 1. Results of nonparametric independent samples tests of dependent variables from SPSS.

Furthermore, a general linear multivariate model analysis was conducted; again, it validated and confirmed the results of the independent samples *t*-test and the nonparametric independent samples tests that indeed there are overwhelmingly significant differences in student performance as measured through exams scores and final class grades as summarized in the results of Tables 3 and 4, particularly on the type of class (traditional—passive, teacher-centered learning pedagogy versus experimental—active, student-centered learning pedagogy).

The results of the general linear multivariate model analysis, as summarized in Table 3, show that the *p*-values of major, class type, and semester reveal that these variables may be used as statistically significant predictors of class performance across exam grades and class grades in statics of engineering as tested using four different effects, Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root.

Examining the *p*-values of *class type* for *exam scores* and *class grade* in Table 4 reconfirms the critical results of the independent samples *t*-test and the nonparametric independent samples test that there is a statistically significant difference between the experimentally-taught students (active learning) and the traditionally-taught students (passive learning) in statics of engineering.

Table 3

Multivariate Tests[a]

	Effect	Value	*F*	Hypothesis df	Error df	*p*	Partial Eta Squared	Noncentrality Parameter	Observed Power[d]
gender	Pillai's Trace	.003	.170[b]	6.000	349.000	.985	.003	1.019	.094
	Wilks' Lambda	.997	.170[b]	6.000	349.000	.985	.003	1.019	.094
	Hotelling's Trace	.003	.170[b]	6.000	349.000	.985	.003	1.019	.094
	Roy's Largest Root	.003	.170[b]	6.000	349.000	.985	.003	1.019	.094
major	Pillai's Trace	.167	1.452	42.000	2124.000	.031	.028	60.986	.997
	Wilks' Lambda	.841	1.467	42.000	1640.407	.028	.028	47.955	.980
	Hotelling's Trace	.179	1.477	42.000	2084.000	.025	.029	62.030	.998
	Roy's Largest Root	.091	4.597[c]	7.000	354.000	.000	.083	32.180	.994
class type	Pillai's Trace	.267	21.147[b]	6.000	349.000	.000	.267	126.883	1.000
	Wilks' Lambda	.733	21.147[b]	6.000	349.000	.000	.267	126.883	1.000
	Hotelling's Trace	.364	21.147[b]	6.000	349.000	.000	.267	126.883	1.000
	Roy's Largest Root	.364	21.147[b]	6.000	349.000	.000	.267	126.883	1.000
semester	Pillai's Trace	.086	5.458[b]	6.000	349.000	.000	.086	32.748	.996
	Wilks' Lambda	.914	5.458[b]	6.000	349.000	.000	.086	32.748	.996
	Hotelling's Trace	.094	5.458[b]	6.000	349.000	.000	.086	32.748	.996
	Roy's Largest Root	.094	5.458[b]	6.000	349.000	.000	.086	32.748	.996

a. Design: gender + major + class type + semester
b. Exact statistic
c. The statistic is an upper bound on F that yields a lower bound on the significance level.
d. Computed using alpha = 0.05

Table 4

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	*F*	*p*	Partial Eta Squared	Noncentrality Parameter	Observed Power[g]
gender	exam 1	48.007	1	48.007	.287	.592	.001	.287	.083
	exam 2	71.176	1	71.176	.252	.616	.001	.252	.079
	exam 3	118.970	1	118.970	.563	.454	.002	.563	.116
	final exam	19.557	1	19.557	.120	.729	.000	.120	.064
	homework	16.578	1	16.578	.031	.861	.000	.031	.053
	final grade	80.616	1	80.616	.525	.469	.001	.525	.112
major	exam 1	645.437	7	92.205	.552	.794	.011	3.865	.239
	exam 2	2390.689	7	341.527	1.209	.297	.023	8.464	.519
	exam 3	2026.133	7	289.448	1.370	.217	.026	9.589	.582
	final exam	1478.164	7	211.166	1.295	.252	.025	9.064	.553
	homework	6888.500	7	984.071	1.817	.083	.035	12.721	.730
	final grade	2225.553	7	317.936	2.071	.046	.039	14.497	.795
class type	exam 1	1677.207	1	1677.207	10.044	.002	.028	10.044	.885
	exam 2	4353.405	1	4353.405	15.414	.000	.042	15.414	.975
	exam 3	3572.760	1	3572.760	16.909	.000	.046	16.909	.984
	final exam	13813.618	1	13813.618	84.702	.000	.193	84.702	1.000
	homework	4.600	1	4.600	.008	.927	.000	.008	.051
	final grade	8158.379	1	8158.379	53.141	.000	.131	53.141	1.000
semester	exam 1	30.689	1	30.689	.184	.668	.001	.184	.071
	exam 2	2.251	1	2.251	.008	.929	.000	.008	.051
	exam 3	2428.731	1	2428.731	11.494	.001	.031	11.494	.922
	final exam	5.855	1	5.855	.036	.850	.000	.036	.054
	homework	9700.304	1	9700.304	17.914	.000	.048	17.914	.988
	final grade	519.885	1	519.885	3.386	.067	.009	3.386	.450

Computed using alpha = 0.05

Limitations of the Study

The results of this study were as expected and were supported by the literature regarding 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 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 sample representative of the college population. The gender ratio strongly favored males, with 347 (85.7%) males and 58 (14.3%) females. Although the gender ratio is considerably less female than the campus as a whole (44%) and less than the majority female population of academia generally, the sample gender distribution more closely reflects the representation of female students within engineering majors.
3. The enrollment ratio strongly favored the traditional-style lecture, with 297 (73.3%) students enrolled in the traditional-style lecture and 108 (26.7%) students were enrolled in the experimental-style lecture.
4. The enrollment ratio also strongly favored the fall semester lecture, with 257 (63.5%) students enrolled in the fall semester lecture and 148 (36.5%) students were enrolled in the spring semester lecture.

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 pedagogy class in terms of student understanding and data collected from

fall 2012 and 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 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 with teaching assignments assigned by college administrators.

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

Conclusions

This study was begun in hopes of being able to answer the research question of whether there is a difference in student performance in an IFEM class of statics of engineering between the *traditional*, 50-minute, three times a week, teacher-centered pedagogy class (passive learning) and an *experimental*, 50-minute, three times a week, student-centered pedagogy class that involved interventions including supplemental videos and interactive-teaching style (active learning). The results, as tested using an independent samples *t*-test and validated using a nonparametric independent samples test and a general linear multivariate model analysis, overwhelmingly showed that the students in the class taught actively using the student-centered pedagogy significantly outperformed the students in the class taught passively using the teacher-centered pedagogy, as summarized below:

1. The type of class (traditional or experimental), the time of year (fall or spring), and major, do predict student performance across exam grades and class grades in statics of engineering.
2. Gender (male or female) does not predict student performance across exam grades and class grades in statics of engineering.
3. There is a statistically significant difference between the experimentally-taught students (active learning) and the traditionally-taught students (passive learning) in student performance on exam scores and class grades results in statics of engineering.

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 behemoth. 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 student-centered 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.

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CHAPTER 3. A CASE FOR THE NEED OF REFORM IN TEACHING INTRODUCTORY, FUNDAMENTAL ENGINEERING MECHANICS CLASSES

A paper submitted to the Journal of Engineering Education

Peggy Boylan-Ashraf, Steven A. Freeman, Mack C. Shelley

Abstract

Introductory, fundamental engineering mechanics (IFEM) courses, such as statics of engineering, mechanics of materials, dynamics, and mechanics of fluids, have far too long been focused on intense mathematical and theoretical concepts. Bold new methodologies that connect science to life using active learning pedagogies need to be emphasized more in engineering classrooms. This study investigated the role of a new paradigm in teaching IFEM courses and attempts to contribute to the current national conversation in engineering curriculum development of the need to change engineering education—from passive learning to active learning. Demographic characteristics in this study included a total of 4,937 students, of whom 4,282 (86.7%) are males and 655 (13.3%) are females, over a period of seven years, from 2006 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 an independent samples *t*-test and validated using a nonparametric independent samples test and a general linear univariate model analysis, indicated that overwhelmingly there is a difference between classes taught passively using the teacher-centered pedagogy and classes taught actively using the student-centered pedagogy.

The principal focus of this work was to formulate a convincing argument using data accumulated over seven years that a new paradigm utilizing student-centered pedagogies in teaching IFEM courses should be more emphasized, to move engineering curriculum towards a

more active and student-centered state. 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 a reform but hesitant to abandon conventional teaching practices. By promoting this new paradigm, the potential for improving understanding of engineering fundamentals on a larger scale may be realized.

Introduction

IFEM courses, which include statics of engineering, mechanics of materials, dynamics, and mechanics of fluids, are essential components to many engineering disciplines (Steif & Dollar, 2008). The focus of the new paradigm was using student-centered learning to promote better understanding of conceptual fundamental knowledge for students.

Student-centered learning was first introduced as early as the 1960s under a reform pedagogy called guided inquiry (Karplus & Their, 1969). It was introduced in 3 phases: an exploration phase, an invention phase, and an application phase. This pedagogy has been found to provide students with a significantly better conceptual understanding compared to students who were taught traditionally (Barman, Barman, & Miller, 2010; Marek, Cowan, & Cavallo,1994; Stephans, Dyche, & Beiswenger, 1988).

Traditionally-taught students are understood as those whose instruction primarily focuses on verbal and printed words, rote memorization, and is instruction driven (Schneider & Renner, 1980). Students who are taught traditionally are told what they are expected to know and concepts are presented deductively (Cooper & Robinson, 2000; Huba & Freed, 2000), where the instructor conducts lessons by introducing and explaining concepts to students, and then expecting students to complete tasks to practice the concepts. Modern interpretations of student-centered learning include project-based learning, case-based learning, discovery learning, and just-in-time teaching with 3 instructional approaches of active learning, cooperative learning, and problem-based learning (Prince & Felder, 2006).

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 in large lectures, and to compare the *traditional pedagogy*, which is the full 50-minute lecture, three times a week to an *experimental pedagogy*, which is the 50-minute, three times a week class centered on active learning. The variables included demographic characteristics and grades earned in class. This study was conducted using data over a period of seven years—from 2006 to 2013—in statics of engineering (EM 274) at Iowa State University (ISU) from multiple instructors teaching multiple sections.

Statics of engineering was chosen because its concepts and applications are needed in almost every discipline of engineering (Benson et al., 2010; Rutz et al., 2003). It is a fundamental prerequisite for subsequent courses such as mechanics of materials, dynamics, and mechanics of fluids, and in some programs, other courses such as tool design (Beer & Johnston, 2004; Orr, Benson, & Biggers, 2008). Many researchers (Beer & Johnston, 2004; Benson et al., 2010; Rutz et al., 2003; Orr et al., 2008) believe that performance in these later courses can be directly correlated to success in statics of engineering.

In the past statics of engineering has often been taught in a traditional lecture and note-taking approach. According to current understanding (Thomas, Subramaniam, Abraham, Too, & Beh, 2011; Zorn & Kumler, 2003), humans think, learn, and solve problems by making connections and associations to previous experiences. Numerous researchers (Gleason, 1986; Thomas et al., 2011; Zorn & Kumler, 2003) have written that if one's first exposure to fundamental concepts takes place by passively hearing it in lecture or by reading it in a textbook, the experience may not be sufficiently significant or rich to build connections. Thus, determining factors that could facilitate academic success in statics of engineering should be a major concern in engineering education generally and its curriculum development more specifically.

Literature Review

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

The major emphasis on curriculum development in engineering education since the early 1970s has been on the implementation process of how to teach our engineering students better (Busch-Vishniac et al., 2011; Rompelman & De Graaff, 2006; Walkington, 2002). To this day, curriculum development in engineering education has continued to be a pressing problem that will require our best thinking and perhaps a stronger collective movement into a new and different form of teaching engineering classes, particularly IFEM classes, such as: statics of engineering, mechanics of materials, dynamics, and mechanics of fluids. Numerous discussions in IFEM courses have focused on the teaching delivery (Al Nashash & Gunn, 2013; Boxall & Tait, 2008; Mackechnie & Buchanan, 2012; Schkoda, Schweisinger, & Wagner, 2012) and what would make a meaningful curriculum (Ahern, 2012; Busch-Vishniac et al., 2011; Saunders & Gale, 2012). From policy makers, to curriculum specialists, to university educators, and to parent groups, people have been trying to decide on the best way to teach students. Discussions have revolved around project-based learning, case-based learning, discovery learning, and just-in-time teaching with three instructional approaches of active learning, cooperative learning, and problem-based learning (Prince & Felder, 2006).

Decades ago, the education philosopher, Dewey (1938), suggested a profound curriculum change. Dewey believed that all genuine education comes from experience and spoke of two forms of education—traditional and progressive. Dewey argued that every experience lives on in further experiences and that traditional education offers the type of experiences that are not genuine, whereas progressive education insists upon the quality of the experience. The type of curriculum Dewey recommended does not come from "experts" outside the classroom; but is to be created with the instructor and students inside the classroom.

Emphasizing on Dewey's principles, several other scholars emerged within the last two decades ago. Alwerger and Flores (1994) 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" (p.2). Harste (1993) stated that curriculum is a meaning-making potential where knowledge is created, acted upon, and recreated at the point of experience, and that it provides opportunities for both instructor and students to experience themselves as learners, engaged together in inquiry to create, critique, and transcend their present knowledge.

Numerous other scholars of engineering education (Larkin-Hein & Budny, 2001; Mackechnie & Buchanan, 2012; Pendergrass et al., 2013; Savage, Chen, Vanasupa, 2007), who have emerged within the past decade, have built upon Dewey and his contemporaries' recommendations, from the previous century, that active, cooperative, problem-based learning is the theme to be suggested when discussing a new curriculum development for introductory, fundamental engineering classes. The theme strongly suggests that instructor and students work together to create new understandings (Pendergrass et al., 2013). In this new approach, 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 (Savage et al., 2007). Savage et al. (2007) believe that when instructor and students in IFEM courses, such as, statics of engineering, mechanics of materials, dynamics, and mechanics of fluids participate in a curriculum that is generated by active and cooperative learning, as suggested by Dewey and numerous other scholars, a stronger development of student learning in engineering concepts should occur.

The Role of the Instructor in Developing a New Curriculum in Engineering Education

The different roles assumed by faculty members reflect the type of curriculum used in the engineering classrooms. Some instructor enjoy the authoritarian stance and provide students the traditional education—where instruction primarily focuses on verbal and printed words, rote memorization, and is instruction-driven (Schneider & Renner, 1980). In the traditional education format students are told what they are expected to know and concepts are presented deductively (Cooper & Robinson, 2000; Huba & Freed, 2000). Other instructor become too laissez-faire and become a silent member of the classroom or mainly an observer—where instruction primarily allows students to grow and learn on their own with little or no extrinsic help (Miller, 2011).

The role of the instructor in the classroom for course development in engineering education cannot be divorced from the understanding of theories of learning and the effectiveness of student 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 (Schunk, 2011).

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 (Faleye, 2011; Kelley & Kellam, 2009; Stier & Laigen, 2010; Zascerinska, 2010). Out of the six paradigms, researchers (Kazakci, 2013; Kelley & Kellam, 2009; Stier & Laigen, 2010) believe that constructivism aligns best with engineering education. It is a theory of learning founded on the premise that a learner's knowledge comes from his/her previous knowledge, much like the purposeful, reflective, and methodical nature of engineering. There are several guiding principles of constructivism (Gopnik & Wellman, 2012; Kelley & Kellam, 2009; Martell, 2012; Savasci & Berlin, 2012; Stier & Laigen, 2010):

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

The constructivism view encourages instructors to be aware of their students' capacities and needs and agrees much with Dewey (1938) and numerous other scholars mentioned above that: 1) learning is social, 2) learners need choices to connect to personal experiences, and 3) learning is active and reflective.

The literature suggests that a change in the development of curriculum in teaching IFEM courses is worth exploring. When compared to implementation strategies of learning theories, the active learning model combined with the cooperative learning model, in line with the constructivism view, appears to provide a strong framework for fostering the development of student understanding of fundamental engineering concepts.

Research Question

This study sought to answer the research question *do constructivist pedagogies using different levels of interventions improve student performance measured through comparisons of final class grades of different cohorts taught by a single faculty member?*

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 population from which the respondents were drawn are students enrolled in statics of engineering (EM 274) classes 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 students (15.7%); agricultural engineering, 208 students (4.2%); civil engineering, 792 students (16.0%); construction engineering, 492 students (10.0%); industrial engineering, 372 students (7.5%); materials engineering, 251 students (5.1%); and mechanical engineering, 1,732 students (35.1%). There were 314 students (6.4%) who were enrolled outside the majors mentioned above.

Design and Procedure

This study aimed to answer the overarching question of whether there is a difference in student performance in IFEM classes of statics of engineering between the traditional 50-minute, three times a week, teacher-centered pedagogy class (passive learning) and an experimental, 50-minute, three times a week, student-centered pedagogy class, which involved interventions including supplemental videos and interactive-teaching style (active learning). The comparison was designed to focus on student final class grades conducted using data over a period of seven years, from 2006 to 2013, in statics of engineering (EM 274) at ISU from multiple instructors teaching multiple sections.

Passive learning featured in this study is the typical lecture format wherein the faculty member speaks at the front of the room and the class sits facing the instructor. Interaction between the teacher 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 play an active role in learning by exploring issues and ideas under the guidance of the instructor. Instead of memorizing, and being mesmerized by a set of often loosely connected facts, the students learn a way of thinking, asking questions, searching for answers, and interpreting observations.

In this research, a cross-sectional, ex-post facto study was carried out on two groups of participants over the period of seven years—from fall 2006 to spring 2013: 1) undergraduate students at ISU who were enrolled in the traditional (passive learning) statics of engineering classes from fall 2006 to spring 2013, and 2) undergraduate students at ISU who were enrolled in the experimental (active learning) pedagogy statics of engineering classes from fall 2006 to spring 2013.

Independent Variable

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

Dependent Variable

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

A student database was obtained from the Office of the Registrar at ISU. One of the authors of this paper taught the experimental, student-centered pedagogy classes continuously each semester from fall 2006 to spring 2013. Multiple (ten) members of the faculty from the aerospace engineering department at ISU taught the traditional, teacher-centered pedagogy classes from fall 2006 to spring 2013 (L. Sturges, personal communication, October 17, 2013).

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 using student-centered pedagogy on their academic learning. With the hope of effectively investigating the most fruitful way to teach IFEM courses, this study aimed to answer the overarching question of whether there is a difference in student performance in IFEM classes of statics of engineering between the traditional 50-minute, three times a week classes (passive, teacher-centered learning pedagogy) and the experimental pedagogy, 50-minute, three times a week classes, that involved interventions including supplemental videos and interactive-teaching style (active, student-centered learning pedagogy), using think-pair-share, one-minute muddiest point, and problem solving in groups (Prince & Felder, 2006). 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 any statistical analysis and all results are presented in aggregate form such that no individuals can be identified. This process ensures that the investigators of this project cannot identify the individuals to whom the data pertain. An exempt classification for the human subjects research office was obtained from the ISU Institutional Review Board.

Active learning pedagogies, which involved think-pair-share, one-minute muddiest point, and problem solving in groups, for the experimental pedagogy classes, were introduced at the beginning of the research in 2006. Supplemental videos were added as active learning interventions in 2011.

Results and Discussion

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

Out of the 4,937 cases analyzed in this study, 315 cases (6.38%) were missing data on pre-college performances. 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 values* 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 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 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 (labeled "Pooled" in the results and discussion section of this article) to take into account the variance of the missing data. This study presents only results of the fifth imputation as well as the average values of the five imputations—labeled "Pooled".

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 mean greater than that of the traditional class (passive, teacher-centered learning pedagogy), and the standard deviation of the experimental class (active, student-centered learning pedagogy) is less than that of the traditional class (passive, teacher-centered learning pedagogy). The mean shown in the results summarized in Table 1 is out of a 4.00 scale.

Table 1

Descriptive Statistics of Independent Variable

	imputation number	class type	*N*	*M*	*SD*
course grade	5	experimental	2293	3.09	1.00172
		traditional	2644	2.85	1.14858

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

The results show that there was a statistically significant difference in course grade 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, $p < .001$ as seen in the results summarized in Table 2, and that student-centered pedagogy does have an effect on student.

Table 2

Independent Samples t-Test

Imputation Number			Levene's Test for Equality of Variances		t-test for Equality of Means						
			F	*p*	*t*	*df*	*p* (2-tailed)	Mean Difference	Std. Error of Difference	95% Confidence Interval of the Difference Lower	Upper
5	course_grade	Equal variances assumed	57.615	.000	7.910	4935	.000	.24443	.03090	.18385	.30501
		Equal variances not assumed			7.987	4934.843	.000	.24443	.03060	.18443	.30442
Pooled	course_grade	Equal variances assumed			7.910	.	.	.24443	.03090	.	.
		Equal variances not assumed			7.987	.	.	.24443	.03060	.	.

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 nonparametric 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.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of crse_grade is the same across categories of class_type.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.

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

Figure 1. Results of nonparametric independent samples tests of dependent variable from SPSS.

Furthermore, a general linear univariate model analysis was estimated, and 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 3—the tests of between-subjects effect table of class type.

Table 3

Tests of Between-Subjects Effects of Class Type

Dependent Variable: course grade

Imputation Number	Source	Type III Sum of Squares	*df*	Mean Square	*F*	*p*	Partial Eta Squared	Noncentrality. Parameter	Observed Power[b]
5	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
	class type	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

Finally, to answer the overarching 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 of years was estimated to investigate the different comparisons of cohorts taught using the experimental, student-centered pedagogies, which involved interventions including supplemental videos and interactive-teaching style (active learning), as seen in the results summarized in Table 4.

Table 4

Tests of Between-Subjects Effects of Years
Dependent Variable: course grade

year	*M*	*SD*	95% Confidence Interval	
			Lower Bound	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

class type = experimental

Also, a summary of results as seen in Table 5 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, 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.

Table 5

Multiple Comparisons[a]
Dependent Variable: course 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

class_type = experimental

Limitations of Study

The results of this study were as expected and were supported by the review of literature regarding 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 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 4,282 (86.7%) males and 655 (13.3%) females. Although the gender ratio is considerably less females than the campus

as a whole (44%) and less than the majority female population of academic nationally, the sample gender distribution 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 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.

6. 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 begun in hopes of being able to answer the research question of whether there was a difference in student performance in IFEM classes of statics of engineering between the traditional, teacher-centered, 50-minute, three times a week classes (passive learning) and the experimental, student-centered pedagogy, 50-minute, three times a week classes, that involved interventions including supplemental videos and interactive-teaching style (active learning) as escalation of active-learning interventions were injected from one cohort to the next. The results as tested using an independent samples *t*-test and validated using a nonparametric independent samples test and a general linear univariate model analysis, overwhelmingly showed that there was a 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 interventions, which involved the full usage of active learning pedagogies of think-pair-share, one-minute muddiest point, and problem solving in groups, and supplemental videos of active learning are associated with a statistically significant difference in learning compared to lower levels of interventions of active learning in statics of engineering in the experimental classes.

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 behemoth. Any faculty member having the privilege 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 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 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 IFEM classes with critical thinking in upper-level major classes.

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CHAPTER 4. A CASE FOR THE NEED OF USING SCAFFOLDING METHODS IN TEACHING INTRODUCTORY, FUNDAMENTAL ENGINEERING MECHANICS CLASSES

A paper submitted to the Journal of STEM Education

Peggy Boylan-Ashraf, Steven A. Freeman, Mack C. Shelley

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).

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 six 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. 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 can 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 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 pedagogies of active learning versus teacher-centered pedagogies of passive learning were only differentiated in statics of engineering, not in mechanics of materials, because differences of student performance were only seen in statics of engineering.

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 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 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.

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. 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 values* 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 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 (labeled "Pooled" in the results and discussion section of this paper) to take into account the variance of the missing data. This study presents only results of the fifth imputation as well as the average values of the five imputations—labeled "Pooled".

Comparing pre-college performance in Table 1, it is seen that students who were enrolled in the experimental class (active, student-centered learning pedagogy) in statics of engineering started with a 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.

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.

Table 1

Descriptive Statistics of Pre-College Variables

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

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 2 and 3.

Table 2

Descriptive Statistics of Course Grades in Statics between Class Types

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

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

imputation			Levene's Test for Equality of Variances		*t*-test for Equality of Means						
			F	*p*	*t*	*df*	*p* (2-tailed)	Mean Difference	Std. Error of Difference	95% Confidence Interval of the Difference	
										Lower	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

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 1, they performed better in their college class of statics of engineering, as seen in Tables 2 and 3, when subjected to interventions of active learning pedagogies.

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 4 and 5.

Table 4

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

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

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

imputation			Levene's Test for Equality of Variances		*t*-test for Equality of Means						
			F	*p*	*t*	*df*	*p* (2-tailed)	Mean Difference	Std. Error of Difference	95% Confidence Interval of the Difference	
										Lower	Upper
5	course grades in mechanics	Equal variances assumed	.223	.637	2.124	3590	.034	.08437	.03973	.00647	.16226
		Equal variances not assumed			2.124	3589.966	.034	.08437	.03973	.00648	.16226

Due to violations of normality when examining a histogram of the dependent variable, the independent samples *t*-test of Tables 4 and 5 was validated using a nonparametric independent samples tests, as seen in Figure 1.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of crse_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 significances are displayed. The significance level is .05.

Figure 1. Results of nonparametric independent samples test of grades in mechanics of materials from SPSS.

The nonparametric independent samples tests suggest that indeed the distribution of grades in mechanics of materials is the same across categories of class type in statics of engineering.

Second, a general linear univariate model analysis, as seen in Table 6, 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.

Table 6

Tests of Between-Subjects Effects
Dependent Variable: course grade in mechanics

Imputation	Source	Type III Sum of Squares	*df*	Mean Square	*F*	*p*	Partial Eta Squared	Noncentrality Parameter	Observed Power[b]
5	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

Computed using alpha = 0.05

The results in Table 6 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. 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 behemoth. 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.

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CHAPTER 5. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This final chapter provides the overview of the study on a new paradigm of teaching IFEM classes and the effectiveness of student-centered pedagogies compared to the traditional lecture delivery. Highlights on the key findings of the research are presented along with recommendations for faculty, administrators, and researchers.

Overview of the Study

The purpose of this study was to investigate the most effective way to teach IFEM courses in large lectures and to compare the traditional-style pedagogy, which is the full 50-minute lecture, teacher-centered, three times a week classes to an experimental, 50-minute, student-centered, three times a week pedagogy classes centered on constructivism learning styles. The experimental pedagogy classes involved focusing on desired learning and made use of active learning, scaffolding, cooperative learning, and a variety of student-centered techniques to address a broad spectrum of learning styles.

This study was guided by 3 research questions:

1. *Do active learning pedagogies in large classes improve student ability to understand course concepts and learn problem-solving measured through semester examination scores, homework scores, and final class grades?*
2. *Do constructivist pedagogies using different levels of interventions improve student performance measured through comparisons of final class grades of different cohorts taught by a single faculty member?*
3. *Do scaffolding and cooperative learning improve student ability in the next class in the same sequence?*

The first two research questions examined the effects of student-centered pedagogies in one class, statics of engineering; and the last research question examined whether student-centered pedagogies in statics of engineering was a significant predictor in the next class of the same sequence, mechanics of materials.

Summary of the Findings

In some respects, the results were not surprising and were supported by the literature regarding large lectures and student-centered pedagogies.

Research Question 1: *Do active learning pedagogies in large classes improve student ability to understand course concepts and learn problem-solving measured through semester examination scores, homework scores, and final class grades?*

The following conclusions are based upon the findings related to research question 1:

1. The type of class (traditional or experimental), the time of year (fall 2012 or spring 2013), and the type of engineering program, do predict student performance across exam grades and class grades in statics of engineering.
2. Gender (male or female) does not predict student performance across exam grades and class grades in statics of engineering.
3. There is a statistically significant difference between the experimentally-taught students (active learning) and the traditionally-taught students (passive learning) in student performance when examining exam scores and class grades results in statics of engineering.
4. There is a statistically significant difference between the experimentally-taught students (active learning) and the traditionally-taught students (passive learning) in student performance when examining homework results in statics of engineering.

Research Question 2: *Do constructivist pedagogies using different levels of interventions improve student performance measured through comparisons of final class grades of different cohorts taught by a single faculty member?*

The following conclusions are based upon the findings related to research question 2:

1. The type of class (traditional or experimental) does predict performance across course grade in statics of engineering.
2. High levels of injection of intervention of active learning creates a statistically significant difference in learning compared to lower levels of active learning in statics of engineering.

Research Question 3: *Do scaffolding and cooperative learning improve student ability in the next class in the same sequence?*

The following conclusions are based upon the findings related to research question 3:

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.

Conclusion

With a review of the literature indicating the strength of student-centered pedagogies applied in IFEM classrooms, it appears that there is justification for a call for change in engineering education. When considering the micro-level (settings where teaching and learning take place –the engineering classrooms), there is major support for the need for students to learn in an active, cooperative learning environment. The results of this study will perhaps be a motivation for positive education changes in the engineering classrooms where educators and students interact.

Recommendations

The author's recommendation is that large IFEM classes, such as statics of engineering, mechanics of materials, dynamics, and fluid dynamics do not have to be engineering's behemoth. Any faculty having the privilege 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 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. Additional studies to determine which student-centered strategies engineering professors are most comfortable with and use most effectively.
4. Additional studies to determine which student-centered strategies have the greatest impact on student learning.
5. Additional studies to determine which training techniques are most effective in working with engineering faculty to increase their use of student-centered strategies.
6. Additional studies to determine the effects of student-centered learning in dynamics and fluid dynamics.

7. Additional studies to determine the effects of student-centered learning in upper-level classes.

8. Additional studies to explore the correlation of student-centered learning in introductory, fundamental classes, such as statics of engineering, mechanics of materials, dynamics, and fluid dynamics with critical thinking in upper-level major classes.

APPENDIX A. STATISTICAL RESULTS

Chapter 2

Table 1

Group Statistics

	ClassType	N	Mean	Std. Deviation	Std. Error Mean
Exam1	1	108	89.45	10.795	1.039
	0	297	81.60	13.530	.785
Exam2	1	108	86.22	12.368	1.190
	0	297	70.52	18.198	1.056
Exam3	1	108	90.49	10.362	.997
	0	297	81.72	16.531	.959
Final	1	108	87.708	11.3882	1.0958
	0	297	61.283	14.1708	.8223
HW	1	108	77.64	21.102	2.031
	0	297	84.99	25.102	1.457
Grade	1	108	91.69	7.481	.720
	0	297	74.99	14.177	.823

Table 2

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Exam1	Equal variances assumed	6.033	.014	5.435	403	.000	7.854	1.445	5.013	10.695
	Equal variances not assumed			6.032	236.288	.000	7.854	1.302	5.289	10.419
Exam2	Equal variances assumed	16.017	.000	8.293	403	.000	15.700	1.893	11.979	19.422
	Equal variances not assumed			9.868	279.232	.000	15.700	1.591	12.568	18.832
Exam3	Equal variances assumed	3.953	.047	5.153	403	.000	8.767	1.701	5.422	12.111
	Equal variances not assumed			6.336	302.913	.000	8.767	1.384	6.044	11.489
Final	Equal variances assumed	.543	.462	17.436	403	.000	26.4255	1.5156	23.4460	29.4050
	Equal variances not assumed			19.288	234.535	.000	26.4255	1.3700	23.7264	29.1246
HW	Equal variances assumed	.730	.393	-2.715	403	.007	-7.354	2.709	-12.679	-2.030
	Equal variances not assumed			-2.943	224.005	.004	-7.354	2.499	-12.279	-2.430
Grade	Equal variances assumed	8.926	.003	11.660	403	.000	16.701	1.432	13.885	19.517
	Equal variances not assumed			15.278	351.947	.000	16.701	1.093	14.551	18.851

Figure 1

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Exam1 is the same across categories of ClassType.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.
2	The distribution of Exam2 is the same across categories of ClassType.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.
3	The distribution of Exam3 is the same across categories of ClassType.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.
4	The distribution of Final is the same across categories of ClassType.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.
5	The distribution of HW is the same across categories of ClassType.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.
6	The distribution of Grade is the same across categories of ClassType.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.

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

Table 3

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Intercept	Pillai's Trace	.922	684.674[b]	6.000	349.000	.000	.922	4108.044	1.000
	Wilks' Lambda	.078	684.674[b]	6.000	349.000	.000	.922	4108.044	1.000
	Hotelling's Trace	11.771	684.674[b]	6.000	349.000	.000	.922	4108.044	1.000
	Roy's Largest Root	11.771	684.674[b]	6.000	349.000	.000	.922	4108.044	1.000
ClassType	Pillai's Trace	.267	21.147[b]	6.000	349.000	.000	.267	126.883	1.000
	Wilks' Lambda	.733	21.147[b]	6.000	349.000	.000	.267	126.883	1.000
	Hotelling's Trace	.364	21.147[b]	6.000	349.000	.000	.267	126.883	1.000
	Roy's Largest Root	.364	21.147[b]	6.000	349.000	.000	.267	126.883	1.000
Semester	Pillai's Trace	.086	5.458[b]	6.000	349.000	.000	.086	32.748	.996
	Wilks' Lambda	.914	5.458[b]	6.000	349.000	.000	.086	32.748	.996
	Hotelling's Trace	.094	5.458[b]	6.000	349.000	.000	.086	32.748	.996
	Roy's Largest Root	.094	5.458[b]	6.000	349.000	.000	.086	32.748	.996
Gender	Pillai's Trace	.003	.170[b]	6.000	349.000	.985	.003	1.019	.094
	Wilks' Lambda	.997	.170[b]	6.000	349.000	.985	.003	1.019	.094
	Hotelling's Trace	.003	.170[b]	6.000	349.000	.985	.003	1.019	.094
	Roy's Largest Root	.003	.170[b]	6.000	349.000	.985	.003	1.019	.094
Major	Pillai's Trace	.167	1.452	42.000	2124.000	.031	.028	60.986	.997
	Wilks' Lambda	.841	1.467	42.000	1640.407	.028	.028	47.955	.980
	Hotelling's Trace	.179	1.477	42.000	2084.000	.025	.029	62.030	.998
	Roy's Largest Root	.091	4.597[c]	7.000	354.000	.000	.083	32.180	.994
ClassType *	Pillai's Trace	.156	10.779[b]	6.000	349.000	.000	.156	64.674	1.000
	Wilks' Lambda	.844	10.779[b]	6.000	349.000	.000	.156	64.674	1.000
	Hotelling's Trace	.185	10.779[b]	6.000	349.000	.000	.156	64.674	1.000

Table 3 continued

Semester	Roy's Largest Root	.185	10.779[b]	6.000	349.000	.000	.156	64.674	1.000
ClassType * Gender	Pillai's Trace	.042	2.527[b]	6.000	349.000	.021	.042	15.164	.840
	Wilks' Lambda	.958	2.527[b]	6.000	349.000	.021	.042	15.164	.840
	Hotelling's Trace	.043	2.527[b]	6.000	349.000	.021	.042	15.164	.840
	Roy's Largest Root	.043	2.527[b]	6.000	349.000	.021	.042	15.164	.840
ClassType * Major	Pillai's Trace	.210	1.835	42.000	2124.000	.001	.035	77.069	1.000
	Wilks' Lambda	.798	1.921	42.000	1640.407	.000	.037	62.747	.998
	Hotelling's Trace	.242	2.003	42.000	2084.000	.000	.039	84.126	1.000
	Roy's Largest Root	.193	9.761[c]	7.000	354.000	.000	.162	68.327	1.000
Semester * Gender	Pillai's Trace	.016	.917[b]	6.000	349.000	.482	.016	5.504	.363
	Wilks' Lambda	.984	.917[b]	6.000	349.000	.482	.016	5.504	.363
	Hotelling's Trace	.016	.917[b]	6.000	349.000	.482	.016	5.504	.363
	Roy's Largest Root	.016	.917[b]	6.000	349.000	.482	.016	5.504	.363
Semester * Major	Pillai's Trace	.185	1.613	42.000	2124.000	.008	.031	67.752	.999
	Wilks' Lambda	.825	1.630	42.000	1640.407	.007	.031	53.289	.991
	Hotelling's Trace	.199	1.642	42.000	2084.000	.006	.032	68.949	.999
	Roy's Largest Root	.102	5.141[c]	7.000	354.000	.000	.092	35.989	.998
Gender * Major	Pillai's Trace	.187	1.903	36.000	2124.000	.001	.031	68.492	1.000
	Wilks' Lambda	.821	1.956	36.000	1535.327	.001	.032	51.221	.992
	Hotelling's Trace	.207	1.999	36.000	2084.000	.000	.033	71.975	1.000
	Roy's Largest Root	.146	8.587[c]	6.000	354.000	.000	.127	51.519	1.000
ClassType * Semester * Gender	Pillai's Trace	.096	6.196[b]	6.000	349.000	.000	.096	37.176	.999
	Wilks' Lambda	.904	6.196[b]	6.000	349.000	.000	.096	37.176	.999
	Hotelling's Trace	.107	6.196[b]	6.000	349.000	.000	.096	37.176	.999
	Roy's Largest Root	.107	6.196[b]	6.000	349.000	.000	.096	37.176	.999

Table 3 continued

ClassType * Semester * Major	Pillai's Trace	.190	2.323	30.000	1765.000	.000	.038	69.689	1.000
	Wilks' Lambda	.816	2.437	30.000	1398.000	.000	.040	58.195	.999
	Hotelling's Trace	.220	2.543	30.000	1737.000	.000	.042	76.282	1.000
	Roy's Largest Root	.186	10.947[c]	6.000	353.000	.000	.157	65.680	1.000
ClassType * Gender * Major	Pillai's Trace	.166	2.547	24.000	1408.000	.000	.042	61.133	1.000
	Wilks' Lambda	.839	2.626	24.000	1218.726	.000	.043	54.785	.999
	Hotelling's Trace	.186	2.696	24.000	1390.000	.000	.044	64.709	1.000
	Roy's Largest Root	.149	8.715[c]	6.000	352.000	.000	.129	52.290	1.000
Semester * Gender * Major	Pillai's Trace	.172	2.096	30.000	1765.000	.000	.034	62.876	.999
	Wilks' Lambda	.835	2.150	30.000	1398.000	.000	.035	51.363	.995
	Hotelling's Trace	.190	2.195	30.000	1737.000	.000	.037	65.844	1.000
	Roy's Largest Root	.137	8.035[c]	6.000	353.000	.000	.120	48.212	1.000
ClassType * Semester * Gender * Major	Pillai's Trace	.103	3.170	12.000	700.000	.000	.052	38.035	.995
	Wilks' Lambda	.898	3.225[b]	12.000	698.000	.000	.053	38.702	.996
	Hotelling's Trace	.113	3.280	12.000	696.000	.000	.054	39.365	.996
	Roy's Largest Root	.105	6.127[c]	6.000	350.000	.000	.095	36.759	.999

a. Design: Intercept + ClassType + Semester + Gender + Major + ClassType * Semester + ClassType * Gender + ClassType * Major + Semester * Gender + Semester * Major + Gender * Major + ClassType * Semester * Gender + ClassType * Semester * Major + ClassType * Gender * Major + Semester * Gender * Major + ClassType * Semester * Gender * Major

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha = 0.05

Table 4

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[g]
Corrected Model	Exam1	12426.652[a]	50	248.533	1.4	.022	.174	74.417	.999
	Exam2	33928.794[b]	50	678.576	2.403	.000	.253	120.129	1.000
	Exam3	23666.577[c]	50	473.332	2.240	.000	.240	112.007	1.000
	Final	70891.086[d]	50	1417.822	8.694	.000	.551	434.687	1.000
	HW	46750.367[e]	50	935.007	1.727	.003	.196	86.334	1.000
	Grade	33223.047[f]	50	664.461	4.328	.000	.379	216.405	1.000
Intercept	Exam1	566285.148	1	566285.148	3391.194	.000	.905	3391.194	1.000
	Exam2	458759.027	1	458759.027	1624.286	.000	.821	1624.286	1.000
	Exam3	535514.984	1	535514.984	2534.427	.000	.877	2534.427	1.000
	Final	427816.908	1	427816.908	2623.273	.000	.881	2623.273	1.000
	HW	494207.886	1	494207.886	912.659	.000	.721	912.659	1.000
	Grade	511781.351	1	511781.351	3333.586	.000	.904	3333.586	1.000
ClassType	Exam1	1677.207	1	1677.207	10.044	.002	.028	10.044	.885
	Exam2	4353.405	1	4353.405	15.414	.000	.042	15.414	.975
	Exam3	3572.760	1	3572.760	16.909	.000	.046	16.909	.984
	Final	13813.618	1	13813.618	84.702	.000	.193	84.702	1.000
	HW	4.600	1	4.600	.008	.927	.000	.008	.051
	Grade	8158.379	1	8158.379	53.141	.000	.131	53.141	1.000
Semester	Exam1	30.689	1	30.689	.184	.668	.001	.184	.071
	Exam2	2.251	1	2.251	.008	.929	.000	.008	.051
	Exam3	2428.731	1	2428.731	11.494	.001	.031	11.494	.922
	Final	5.855	1	5.855	.036	.850	.000	.036	.054
	HW	9700.304	1	9700.304	17.914	.000	.048	17.914	.988
	Grade	519.885	1	519.885	3.386	.067	.009	3.386	.450
Gender	Exam1	48.007	1	48.007	.287	.592	.001	.287	.083
	Exam2	71.176	1	71.176	.252	.616	.001	.252	.079
	Exam3	118.970	1	118.970	.563	.454	.002	.563	.116
	Final	19.557	1	19.557	.120	.729	.000	.120	.064
	HW	16.578	1	16.578	.031	.861	.000	.031	.053
	Grade	80.616	1	80.616	.525	.469	.001	.525	.112

Table 4 continued

Major	Exam1	645.437	7	92.205	.552	.794	.011	3.865	.239
	Exam2	2390.689	7	341.527	1.209	.297	.023	8.464	.519
	Exam3	2026.133	7	289.448	1.370	.217	.026	9.589	.582
	Final	1478.164	7	211.166	1.295	.252	.025	9.064	.553
	HW	6888.500	7	984.071	1.817	.083	.035	12.721	.730
	Grade	2225.553	7	317.936	2.071	.046	.039	14.497	.795
ClassType * Semester	Exam1	194.404	1	194.404	1.164	.281	.003	1.164	.190
	Exam2	49.644	1	49.644	.176	.675	.000	.176	.070
	Exam3	3.395	1	3.395	.016	.899	.000	.016	.052
	Final	263.450	1	263.450	1.615	.205	.005	1.615	.245
	HW	1581.499	1	1581.499	2.921	.088	.008	2.921	.399
	Grade	120.051	1	120.051	.782	.377	.002	.782	.143
ClassType * Gender	Exam1	33.979	1	33.979	.203	.652	.001	.203	.073
	Exam2	109.290	1	109.290	.387	.534	.001	.387	.095
	Exam3	110.926	1	110.926	.525	.469	.001	.525	.112
	Final	73.769	1	73.769	.452	.502	.001	.452	.103
	HW	602.464	1	602.464	1.113	.292	.003	1.113	.183
	Grade	33.317	1	33.317	.217	.642	.001	.217	.075
ClassType * Major	Exam1	671.532	7	95.933	.574	.777	.011	4.021	.249
	Exam2	835.038	7	119.291	.422	.888	.008	2.957	.187
	Exam3	316.280	7	45.183	.214	.982	.004	1.497	.111
	Final	1072.241	7	153.177	.939	.476	.018	6.575	.406
	HW	4517.054	7	645.293	1.192	.307	.023	8.342	.512
	Grade	1527.679	7	218.240	1.422	.195	.027	9.951	.601
Semester * Gender	Exam1	14.810	1	14.810	.089	.766	.000	.089	.060
	Exam2	404.132	1	404.132	1.431	.232	.004	1.431	.222
	Exam3	5.234	1	5.234	.025	.875	.000	.025	.053
	Final	9.446	1	9.446	.058	.810	.000	.058	.057
	HW	1191.410	1	1191.410	2.200	.139	.006	2.200	.316
	Grade	3.292	1	3.292	.021	.884	.000	.021	.052
Semester * Major	Exam1	330.843	7	47.263	.283	.960	.006	1.981	.135
	Exam2	1329.466	7	189.924	.672	.695	.013	4.707	.290
	Exam3	2116.286	7	302.327	1.431	.192	.028	10.016	.605
	Final	2249.572	7	321.367	1.971	.058	.038	13.794	.771
	HW	8150.897	7	1164.414	2.150	.038	.041	15.052	.813

Table 4 continued

	Grade	2205.435	7	315.062	2.052	.048	039	14.366	.791
Gender * Major	Exam1	395.559	6	65.926	.395	.882	.007	2.369	.165
	Exam2	1356.560	6	226.093	.801	.570	.013	4.803	.317
	Exam3	1174.499	6	195.750	.926	.476	.015	5.559	.367
	Final	1852.617	6	308.770	1.893	.081	.031	11.360	.701
	HW	2297.579	6	382.930	.707	.644	.012	4.243	.281
	Grade	1181.701	6	196.950	1.283	.264	.021	7.697	.504
ClassType * Semester * Gender	Exam1	352.933	1	352.933	2.114	.147	.006	2.114	.305
	Exam2	743.122	1	743.122	2.631	.106	.007	2.631	.366
	Exam3	31.850	1	31.850	.151	.698	.000	.151	.067
	Final	499.798	1	499.798	3.065	.081	.009	3.065	.415
	HW	.327	1	.327	.001	.980	.000	.001	.050
	Grade	877.253	1	877.253	5.714	.017	.016	5.714	.664
ClassType * Semester * Major	Exam1	645.859	5	129.172	.774	.569	.011	3.868	.278
	Exam2	706.566	5	141.313	.500	.776	.007	2.502	.187
	Exam3	414.785	5	82.957	.393	.854	.006	1.963	.153
	Final	546.591	5	109.318	.670	.646	.009	3.352	.243
	HW	2912.780	5	582.556	1.076	.373	.015	5.379	.384
	Grade	924.912	5	184.982	1.205	.306	.017	6.025	.428
ClassType * Gender * Major	Exam1	608.271	4	152.068	.911	.458	.010	3.643	.289
	Exam2	1350.435	4	337.609	1.195	.313	.013	4.781	.375
	Exam3	945.580	4	236.395	1.119	.347	.012	4.475	.352
	Final	667.697	4	166.924	1.024	.395	.011	4.094	.323
	HW	685.798	4	171.449	.317	.867	.004	1.266	.121
	Grade	1114.228	4	278.557	1.814	.125	.020	7.258	.551
Semester * Gender * Major	Exam1	233.903	5	46.781	.280	.924	.004	1.401	.120
	Exam2	960.946	5	192.189	.680	.639	.010	3.402	.246
	Exam3	1212.068	5	242.414	1.147	.335	.016	5.736	.408
	Final	2484.813	5	496.963	3.047	.010	.041	15.236	.866
	HW	3972.622	5	794.524	1.467	.200	.020	7.336	.515
	Grade	2205.535	5	441.107	2.873	.015	.039	14.366	.843
ClassType * Semester * Gender * Major	Exam1	35.131	2	17.565	.105	.900	.001	.210	.066
	Exam2	292.140	2	146.070	.517	.597	.003	1.034	.135
	Exam3	463.371	2	231.686	1.096	.335	.006	2.193	.242
	Final	146.676	2	73.338	.450	.638	.003	.899	.123

Table 4 continued

	HW	1115.958	2	557.979	1.030	.358	.006	2.061	.230
	Grade	574.745	2	287.373	1.872	.155	.010	3.744	.389

a. R Squared = .174 (Adjusted R Squared = .057)

b. R Squared = .253 (Adjusted R Squared = .148)

c. R Squared = .240 (Adjusted R Squared = .133)

d. R Squared = .551 (Adjusted R Squared = .488)

e. R Squared = .196 (Adjusted R Squared = .083)

f. R Squared = .379 (Adjusted R Squared = .292)

g. Computed using alpha = 0.05

Chapter 3

Table 1

Group Statistics

Imputation Number		class_type	N	Mean	Std. Deviation	Std. Error Mean	Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
Original data	crse_grade	1	2293	3.0921	1.00172	.02092			
		0	2644	2.8476	1.14858	.02234			
1	crse_grade	1	2293	3.0921	1.00172	.02092			
		0	2644	2.8476	1.14858	.02234			
2	crse_grade	1	2293	3.0921	1.00172	.02092			
		0	2644	2.8476	1.14858	.02234			
3	crse_grade	1	2293	3.0921	1.00172	.02092			
		0	2644	2.8476	1.14858	.02234			
4	crse_grade	1	2293	3.0921	1.00172	.02092			
		0	2644	2.8476	1.14858	.02234			
5	crse_grade	1	2293	3.0921	1.00172	.02092			
		0	2644	2.8476	1.14858	.02234			
Pooled	crse_grade	1	2293	3.0921		.02092	.000	.000	1.000
		0	2644	2.8476		.02234	.000	.000	1.000

Table 2

Imputation Number			Levene's Test for Equality of Variances		t-test for Equality of Means						
			F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
										Lower	Upper
	crse_grade	Equal variances assumed	57.615	.000	7.910	4935	.000	.24443	.03090	.18385	.30501
		Equal variances not assumed			7.987	4934.843	.000	.24443	.03060	.18443	.30442
1	crse_grade	Equal variances assumed	57.615	.000	7.910	4935	.000	.24443	.03090	.18385	.30501
		Equal variances not assumed			7.987	4934.843	.000	.24443	.03060	.18443	.30442
2	crse_grade	Equal variances assumed	57.615	.000	7.910	4935	.000	.24443	.03090	.18385	.30501
		Equal variances not assumed			7.987	4934.843	.000	.24443	.03060	.18443	.30442
3	crse_grade	Equal variances assumed	57.615	.000	7.910	4935	.000	.24443	.03090	.18385	.30501

Table 2 continued

		Equal variances not assumed			7.987	4934.843	.000	.24443	.03060	.18443	.30442
		Equal variances assumed	57.615	.000	7.910	4935	.000	.24443	.03090	.18385	.30501
4	crse_grade	Equal variances not assumed			7.987	4934.843	.000	.24443	.03060	.18443	.30442
		Equal variances assumed	57.615	.000	7.910	4935	.000	.24443	.03090	.18385	.30501
5	crse_grade	Equal variances not assumed			7.987	4934.843	.000	.24443	.03060	.18443	.30442

Figure 1

Imputation_ Imputation Number = Original data

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of crse_grade is the same across categories of class_type.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.

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

Imputation_ Imputation Number = 1

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of crse_grade is the same across categories of class_type.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.

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

Figure 1 continued

Imputation_ Imputation Number = 2

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of crse_grade is the same across categories of class_type.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.

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

Imputation_ Imputation Number = 3

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of crse_grade is the same across categories of class_type.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.

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

Figure 1 continued

Imputation_ Imputation Number = 4

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of crse_grade is the same across categories of class_type.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.

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

Imputation_ Imputation Number = 5

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of crse_grade is the same across categories of class_type.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.

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

Table 3

Tests of Between-Subjects Effects

Dependent Variable: crse_grade

Imputation Number	Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Original data	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
	class_type	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						
1	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
	class_type	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						
2	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
	class_type	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						
3	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
	class_type	73.367	1	73.367	62.570	.000	.013	62.570	1.000

Table 3 continued

	Error	5786.632	4935	1.173					
	Total	49150.065	4937						
	Corrected Total	5859.999	4936						
4	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
	class_type	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						
5	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
	class_type	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 4

Tests of Between-Subjects Effects

Dependent Variable: crse_grade

Imputation Number	sem_ccyy	Mean	Std. Error	95% Confidence Interval		Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
				Lower Bound	Upper Bound			
Original data	2006	2.752	.100	2.555	2.948			
	2007	3.052	.046	2.963	3.142			
	2008	3.161	.053	3.058	3.264			
	2009	2.899	.064	2.774	3.024			
	2010	3.050	.040	2.972	3.129			
	2011	3.272	.054	3.165	3.378			
	2012	3.142	.100	2.946	3.337			
	2013	3.563	.115	3.337	3.789			
1	2006	2.752	.100	2.555	2.948			
	2007	3.052	.046	2.963	3.142			
	2008	3.161	.053	3.058	3.264			
	2009	2.899	.064	2.774	3.024			
	2010	3.050	.040	2.972	3.129			
	2011	3.272	.054	3.165	3.378			
	2012	3.142	.100	2.946	3.337			
	2013	3.563	.115	3.337	3.789			
2	2006	2.752	.100	2.555	2.948			
	2007	3.052	.046	2.963	3.142			
	2008	3.161	.053	3.058	3.264			
	2009	2.899	.064	2.774	3.024			
	2010	3.050	.040	2.972	3.129			
	2011	3.272	.054	3.165	3.378			
	2012	3.142	.100	2.946	3.337			
	2013	3.563	.115	3.337	3.789			
3	2006	2.752	.100	2.555	2.948			
	2007	3.052	.046	2.963	3.142			
	2008	3.161	.053	3.058	3.264			
	2009	2.899	.064	2.774	3.024			
	2010	3.050	.040	2.972	3.129			

Table 4 continued

	2011	3.272	.054	3.165	3.378			
	2012	3.142	.100	2.946	3.337			
	2013	3.563	.115	3.337	3.789			
4	2006	2.752	.100	2.555	2.948			
	2007	3.052	.046	2.963	3.142			
	2008	3.161	.053	3.058	3.264			
	2009	2.899	.064	2.774	3.024			
	2010	3.050	.040	2.972	3.129			
	2011	3.272	.054	3.165	3.378			
	2012	3.142	.100	2.946	3.337			
	2013	3.563	.115	3.337	3.789			
5	2006	2.752	.100	2.555	2.948			
	2007	3.052	.046	2.963	3.142			
	2008	3.161	.053	3.058	3.264			
	2009	2.899	.064	2.774	3.024			
	2010	3.050	.040	2.972	3.129			
	2011	3.272	.054	3.165	3.378			
	2012	3.142	.100	2.946	3.337			
	2013	3.563	.115	3.337	3.789			
Pooled	2006	2.752	.100	2.555	2.948	.000	.000	1.000
	2007	3.052	.046	2.963	3.142	.000	.000	1.000
	2008	3.161	.053	3.058	3.264	.000	.000	1.000
	2009	2.899	.064	2.774	3.024	.000	.000	1.000
	2010	3.050	.040	2.972	3.129	.000	.000	1.000
	2011	3.272	.054	3.166	3.378	.000	.000	1.000
	2012	3.142	.100	2.946	3.337	.000	.000	1.000
	2013	3.563	.115	3.337	3.789	.000	.000	1.000

Table 5

Multiple Comparisons

Dependent Variable: crse_grade

Bonferroni

Imputation Number	(I) sem_ ccyy	(J) sem_ ccyy	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Original data	2006	2007	-.3007	.11012	.178	-.6451	.0437
		2008	-.4091*	.11313	.009	-.7629	-.0553
		2009	-.1478	.11878	1.000	-.5192	.2237
		2010	-.2987	.10788	.159	-.6361	.0387
		2011	-.5201*	.11392	.000	-.8764	-.1638
		2012	-.3900	.14135	.164	-.8321	.0521
		2013	-.8116*	.15277	.000	-1.2894	-.3338
	2007	2006	.3007	.11012	.178	-.0437	.6451
		2008	-.1084	.06958	1.000	-.3261	.1092
		2009	.1529	.07843	1.000	-.0924	.3982
		2010	.0020	.06068	1.000	-.1878	.1918
		2011	-.2194	.07087	.056	-.4411	.0022
		2012	-.0893	.10966	1.000	-.4323	.2536
		2013	-.5109*	.12403	.001	-.8988	-.1230
	2008	2006	.4091*	.11313	.009	.0553	.7629
		2007	.1084	.06958	1.000	-.1092	.3261
		2009	.2613*	.08260	.044	.0030	.5197
		2010	.1105	.06598	1.000	-.0959	.3168
		2011	-.1110	.07546	1.000	-.3470	.1250
		2012	.0191	.11268	1.000	-.3333	.3715
		2013	-.4025*	.12671	.042	-.7987	-.0062
	2009	2006	.1478	.11878	1.000	-.2237	.5192
		2007	-.1529	.07843	1.000	-.3982	.0924
		2008	-.2613*	.08260	.044	-.5197	-.0030
		2010	-.1509	.07526	1.000	-.3862	.0845
		2011	-.3723*	.08369	.000	-.6340	-.1106
		2012	-.2422	.11835	1.000	-.6123	.1279
		2013	-.6638*	.13177	.000	-1.0759	-.2517

Table 5 continued

		2006	.2987	.10788	.159	-.0387	.6361
		2007	-.0020	.06068	1.000	-.1918	.1878
	2010	2008	-.1105	.06598	1.000	-.3168	.0959
		2009	.1509	.07526	1.000	-.0845	.3862
		2011	$-.2214^{*}$	.06734	.029	-.4320	-.0108
		2012	-.0913	.10741	1.000	-.4272	.2446
		2013	$-.5130^{*}$	.12205	.001	-.8946	-.1313
		2006	$.5201^{*}$	.11392	.000	.1638	.8764
		2007	.2194	.07087	.056	-.0022	.4411
		2008	.1110	.07546	1.000	-.1250	.3470
	2011	2009	$.3723^{*}$	.08369	.000	.1106	.6340
		2010	$.2214^{*}$	.06734	.029	.0108	.4320
		2012	.1301	.11348	1.000	-.2248	.4850
		2013	-.2915	.12742	.623	-.6900	.1070
		2006	.3900	.14135	.164	-.0521	.8321
		2007	.0893	.10966	1.000	-.2536	.4323
		2008	-.0191	.11268	1.000	-.3715	.3333
	2012	2009	.2422	.11835	1.000	-.1279	.6123
		2010	.0913	.10741	1.000	-.2446	.4272
		2011	-.1301	.11348	1.000	-.4850	.2248
		2013	-.4216	.15244	.160	-.8984	.0551
		2006	$.8116^{*}$	.15277	.000	.3338	1.2894
		2007	$.5109^{*}$	.12403	.001	.1230	.8988
		2008	$.4025^{*}$	.12671	.042	.0062	.7987
	2013	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
		2007	-.3007	.11012	.178	-.6451	.0437
		2008	$-.4091^{*}$	.11313	.009	-.7629	-.0553
1	2006	2009	-.1478	.11878	1.000	-.5192	.2237
		2010	-.2987	.10788	.159	-.6361	.0387
		2011	$-.5201^{*}$	.11392	.000	-.8764	-.1638

Table 5 continued

	2012	-.3900	.14135	.164	-.8321	.0521
	2013	-.8116*	.15277	.000	-1.2894	-.3338
	2006	.3007	.11012	.178	-.0437	.6451
	2008	-.1084	.06958	1.000	-.3261	.1092
	2009	.1529	.07843	1.000	-.0924	.3982
2007	2010	.0020	.06068	1.000	-.1878	.1918
	2011	-.2194	.07087	.056	-.4411	.0022
	2012	-.0893	.10966	1.000	-.4323	.2536
	2013	-.5109*	.12403	.001	-.8988	-.1230
	2006	.4091*	.11313	.009	.0553	.7629
	2007	.1084	.06958	1.000	-.1092	.3261
	2009	.2613*	.08260	.044	.0030	.5197
2008	2010	.1105	.06598	1.000	-.0959	.3168
	2011	-.1110	.07546	1.000	-.3470	.1250
	2012	.0191	.11268	1.000	-.3333	.3715
	2013	-.4025*	.12671	.042	-.7987	-.0062
	2006	.1478	.11878	1.000	-.2237	.5192
	2007	-.1529	.07843	1.000	-.3982	.0924
	2008	-.2613*	.08260	.044	-.5197	-.0030
2009	2010	-.1509	.07526	1.000	-.3862	.0845
	2011	-.3723*	.08369	.000	-.6340	-.1106
	2012	-.2422	.11835	1.000	-.6123	.1279
	2013	-.6638*	.13177	.000	-1.0759	-.2517
	2006	.2987	.10788	.159	-.0387	.6361
	2007	-.0020	.06068	1.000	-.1918	.1878
	2008	-.1105	.06598	1.000	-.3168	.0959
2010	2009	.1509	.07526	1.000	-.0845	.3862
	2011	-.2214*	.06734	.029	-.4320	-.0108
	2012	-.0913	.10741	1.000	-.4272	.2446
	2013	-.5130*	.12205	.001	-.8946	-.1313
	2006	.5201*	.11392	.000	.1638	.8764
	2007	.2194	.07087	.056	-.0022	.4411
2011	2008	.1110	.07546	1.000	-.1250	.3470
	2009	.3723*	.08369	.000	.1106	.6340
	2010	.2214*	.06734	.029	.0108	.4320

Table 5 continued

		2012	.1301	.11348	1.000	-.2248	.4850
		2013	-.2915	.12742	.623	-.6900	.1070
		2006	.3900	.14135	.164	-.0521	.8321
		2007	.0893	.10966	1.000	-.2536	.4323
		2008	-.0191	.11268	1.000	-.3715	.3333
	2012	2009	.2422	.11835	1.000	-.1279	.6123
		2010	.0913	.10741	1.000	-.2446	.4272
		2011	-.1301	.11348	1.000	-.4850	.2248
		2013	-.4216	.15244	.160	-.8984	.0551
		2006	.8116*	.15277	.000	.3338	1.2894
		2007	.5109*	.12403	.001	.1230	.8988
		2008	.4025*	.12671	.042	.0062	.7987
	2013	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
		2007	-.3007	.11012	.178	-.6451	.0437
		2008	-.4091*	.11313	.009	-.7629	-.0553
		2009	-.1478	.11878	1.000	-.5192	.2237
2	2006	2010	-.2987	.10788	.159	-.6361	.0387
		2011	-.5201*	.11392	.000	-.8764	-.1638
		2012	-.3900	.14135	.164	-.8321	.0521
		2013	-.8116*	.15277	.000	-1.2894	-.3338
		2006	.3007	.11012	.178	-.0437	.6451
		2008	-.1084	.06958	1.000	-.3261	.1092
		2009	.1529	.07843	1.000	-.0924	.3982
	2007	2010	.0020	.06068	1.000	-.1878	.1918
		2011	-.2194	.07087	.056	-.4411	.0022
		2012	-.0893	.10966	1.000	-.4323	.2536
		2013	-.5109*	.12403	.001	-.8988	-.1230
		2006	.4091*	.11313	.009	.0553	.7629
		2007	.1084	.06958	1.000	-.1092	.3261
	2008	2009	.2613*	.08260	.044	.0030	.5197
		2010	.1105	.06598	1.000	-.0959	.3168
		2011	-.1110	.07546	1.000	-.3470	.1250

Table 5 continued

	2012	.0191	.11268	1.000	-.3333	.3715
	2013	-.4025*	.12671	.042	-.7987	-.0062
	2006	.1478	.11878	1.000	-.2237	.5192
	2007	-.1529	.07843	1.000	-.3982	.0924
	2008	-.2613*	.08260	.044	-.5197	-.0030
2009	2010	-.1509	.07526	1.000	-.3862	.0845
	2011	-.3723*	.08369	.000	-.6340	-.1106
	2012	-.2422	.11835	1.000	-.6123	.1279
	2013	-.6638*	.13177	.000	-1.0759	-.2517
	2006	.2987	.10788	.159	-.0387	.6361
	2007	-.0020	.06068	1.000	-.1918	.1878
	2008	-.1105	.06598	1.000	-.3168	.0959
2010	2009	.1509	.07526	1.000	-.0845	.3862
	2011	-.2214*	.06734	.029	-.4320	-.0108
	2012	-.0913	.10741	1.000	-.4272	.2446
	2013	-.5130*	.12205	.001	-.8946	-.1313
	2006	.5201*	.11392	.000	.1638	.8764
	2007	.2194	.07087	.056	-.0022	.4411
	2008	.1110	.07546	1.000	-.1250	.3470
2011	2009	.3723*	.08369	.000	.1106	.6340
	2010	.2214*	.06734	.029	.0108	.4320
	2012	.1301	.11348	1.000	-.2248	.4850
	2013	-.2915	.12742	.623	-.6900	.1070
	2006	.3900	.14135	.164	-.0521	.8321
	2007	.0893	.10966	1.000	-.2536	.4323
	2008	-.0191	.11268	1.000	-.3715	.3333
2012	2009	.2422	.11835	1.000	-.1279	.6123
	2010	.0913	.10741	1.000	-.2446	.4272
	2011	-.1301	.11348	1.000	-.4850	.2248
	2013	-.4216	.15244	.160	-.8984	.0551
	2006	.8116*	.15277	.000	.3338	1.2894
	2007	.5109*	.12403	.001	.1230	.8988
2013	2008	.4025*	.12671	.042	.0062	.7987
	2009	.6638*	.13177	.000	.2517	1.0759
	2010	.5130*	.12205	.001	.1313	.8946

Table 5 continued

		2011	.2915	.12742	.623	-.1070	.6900
		2012	.4216	.15244	.160	-.0551	.8984
		2007	-.3007	.11012	.178	-.6451	.0437
		2008	-.4091*	.11313	.009	-.7629	-.0553
		2009	-.1478	.11878	1.000	-.5192	.2237
3	2006	2010	-.2987	.10788	.159	-.6361	.0387
		2011	-.5201*	.11392	.000	-.8764	-.1638
		2012	-.3900	.14135	.164	-.8321	.0521
		2013	-.8116*	.15277	.000	-1.2894	-.3338
		2006	.3007	.11012	.178	-.0437	.6451
		2008	-.1084	.06958	1.000	-.3261	.1092
		2009	.1529	.07843	1.000	-.0924	.3982
	2007	2010	.0020	.06068	1.000	-.1878	.1918
		2011	-.2194	.07087	.056	-.4411	.0022
		2012	-.0893	.10966	1.000	-.4323	.2536
		2013	-.5109*	.12403	.001	-.8988	-.1230
		2006	.4091*	.11313	.009	.0553	.7629
		2007	.1084	.06958	1.000	-.1092	.3261
		2009	.2613*	.08260	.044	.0030	.5197
	2008	2010	.1105	.06598	1.000	-.0959	.3168
		2011	-.1110	.07546	1.000	-.3470	.1250
		2012	.0191	.11268	1.000	-.3333	.3715
		2013	-.4025*	.12671	.042	-.7987	-.0062
		2006	.1478	.11878	1.000	-.2237	.5192
		2007	-.1529	.07843	1.000	-.3982	.0924
		2008	-.2613*	.08260	.044	-.5197	-.0030
	2009	2010	-.1509	.07526	1.000	-.3862	.0845
		2011	-.3723*	.08369	.000	-.6340	-.1106
		2012	-.2422	.11835	1.000	-.6123	.1279
		2013	-.6638*	.13177	.000	-1.0759	-.2517
		2006	.2987	.10788	.159	-.0387	.6361
		2007	-.0020	.06068	1.000	-.1918	.1878
	2010	2008	-.1105	.06598	1.000	-.3168	.0959
		2009	.1509	.07526	1.000	-.0845	.3862
		2011	-.2214*	.06734	.029	-.4320	-.0108

Table 5 continued

		2012	-.0913	.10741	1.000	-.4272	.2446
		2013	-.5130*	.12205	.001	-.8946	-.1313
		2006	.5201*	.11392	.000	.1638	.8764
		2007	.2194	.07087	.056	-.0022	.4411
		2008	.1110	.07546	1.000	-.1250	.3470
	2011	2009	.3723*	.08369	.000	.1106	.6340
		2010	.2214*	.06734	.029	.0108	.4320
		2012	.1301	.11348	1.000	-.2248	.4850
		2013	-.2915	.12742	.623	-.6900	.1070
		2006	.3900	.14135	.164	-.0521	.8321
		2007	.0893	.10966	1.000	-.2536	.4323
		2008	-.0191	.11268	1.000	-.3715	.3333
	2012	2009	.2422	.11835	1.000	-.1279	.6123
		2010	.0913	.10741	1.000	-.2446	.4272
		2011	-.1301	.11348	1.000	-.4850	.2248
		2013	-.4216	.15244	.160	-.8984	.0551
		2006	.8116*	.15277	.000	.3338	1.2894
		2007	.5109*	.12403	.001	.1230	.8988
		2008	.4025*	.12671	.042	.0062	.7987
	2013	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
		2007	-.3007	.11012	.178	-.6451	.0437
		2008	-.4091*	.11313	.009	-.7629	-.0553
		2009	-.1478	.11878	1.000	-.5192	.2237
4	2006	2010	-.2987	.10788	.159	-.6361	.0387
		2011	-.5201*	.11392	.000	-.8764	-.1638
		2012	-.3900	.14135	.164	-.8321	.0521
		2013	-.8116*	.15277	.000	-1.2894	-.3338
		2006	.3007	.11012	.178	-.0437	.6451
		2008	-.1084	.06958	1.000	-.3261	.1092
	2007	2009	.1529	.07843	1.000	-.0924	.3982
		2010	.0020	.06068	1.000	-.1878	.1918
		2011	-.2194	.07087	.056	-.4411	.0022

Table 5 continued

	2012	-.0893	.10966	1.000	-.4323	.2536
	2013	-.5109*	.12403	.001	-.8988	-.1230
	2006	.4091*	.11313	.009	.0553	.7629
	2007	.1084	.06958	1.000	-.1092	.3261
	2009	.2613*	.08260	.044	.0030	.5197
2008	2010	.1105	.06598	1.000	-.0959	.3168
	2011	-.1110	.07546	1.000	-.3470	.1250
	2012	.0191	.11268	1.000	-.3333	.3715
	2013	-.4025*	.12671	.042	-.7987	-.0062
	2006	.1478	.11878	1.000	-.2237	.5192
	2007	-.1529	.07843	1.000	-.3982	.0924
	2008	-.2613*	.08260	.044	-.5197	-.0030
2009	2010	-.1509	.07526	1.000	-.3862	.0845
	2011	-.3723*	.08369	.000	-.6340	-.1106
	2012	-.2422	.11835	1.000	-.6123	.1279
	2013	-.6638*	.13177	.000	-1.0759	-.2517
	2006	.2987	.10788	.159	-.0387	.6361
	2007	-.0020	.06068	1.000	-.1918	.1878
	2008	-.1105	.06598	1.000	-.3168	.0959
2010	2009	.1509	.07526	1.000	-.0845	.3862
	2011	-.2214*	.06734	.029	-.4320	-.0108
	2012	-.0913	.10741	1.000	-.4272	.2446
	2013	-.5130*	.12205	.001	-.8946	-.1313
	2006	.5201*	.11392	.000	.1638	.8764
	2007	.2194	.07087	.056	-.0022	.4411
	2008	.1110	.07546	1.000	-.1250	.3470
2011	2009	.3723*	.08369	.000	.1106	.6340
	2010	.2214*	.06734	.029	.0108	.4320
	2012	.1301	.11348	1.000	-.2248	.4850
	2013	-.2915	.12742	.623	-.6900	.1070
	2006	.3900	.14135	.164	-.0521	.8321
	2007	.0893	.10966	1.000	-.2536	.4323
2012	2008	-.0191	.11268	1.000	-.3715	.3333
	2009	.2422	.11835	1.000	-.1279	.6123
	2010	.0913	.10741	1.000	-.2446	.4272

Table 5 continued

		2011	-.1301	.11348	1.000	-.4850	.2248
		2013	-.4216	.15244	.160	-.8984	.0551
		2006	.8116*	.15277	.000	.3338	1.2894
		2007	.5109*	.12403	.001	.1230	.8988
		2008	.4025*	.12671	.042	.0062	.7987
	2013	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
		2007	-.3007	.11012	.178	-.6451	.0437
		2008	-.4091*	.11313	.009	-.7629	-.0553
		2009	-.1478	.11878	1.000	-.5192	.2237
5	2006	2010	-.2987	.10788	.159	-.6361	.0387
		2011	-.5201*	.11392	.000	-.8764	-.1638
		2012	-.3900	.14135	.164	-.8321	.0521
		2013	-.8116*	.15277	.000	-1.2894	-.3338
		2006	.3007	.11012	.178	-.0437	.6451
		2008	-.1084	.06958	1.000	-.3261	.1092
		2009	.1529	.07843	1.000	-.0924	.3982
	2007	2010	.0020	.06068	1.000	-.1878	.1918
		2011	-.2194	.07087	.056	-.4411	.0022
		2012	-.0893	.10966	1.000	-.4323	.2536
		2013	-.5109*	.12403	.001	-.8988	-.1230
		2006	.4091*	.11313	.009	.0553	.7629
		2007	.1084	.06958	1.000	-.1092	.3261
		2009	.2613*	.08260	.044	.0030	.5197
	2008	2010	.1105	.06598	1.000	-.0959	.3168
		2011	-.1110	.07546	1.000	-.3470	.1250
		2012	.0191	.11268	1.000	-.3333	.3715
		2013	-.4025*	.12671	.042	-.7987	-.0062
		2006	.1478	.11878	1.000	-.2237	.5192
		2007	-.1529	.07843	1.000	-.3982	.0924
	2009	2008	-.2613*	.08260	.044	-.5197	-.0030
		2010	-.1509	.07526	1.000	-.3862	.0845

Table 5 continued

	2011	-.3723*	.08369	.000	-.6340	-.1106
	2012	-.2422	.11835	1.000	-.6123	.1279
	2013	-.6638*	.13177	.000	-1.0759	-.2517
	2006	.2987	.10788	.159	-.0387	.6361
	2007	-.0020	.06068	1.000	-.1918	.1878
	2008	-.1105	.06598	1.000	-.3168	.0959
2010	2009	.1509	.07526	1.000	-.0845	.3862
	2011	-.2214*	.06734	.029	-.4320	-.0108
	2012	-.0913	.10741	1.000	-.4272	.2446
	2013	-.5130*	.12205	.001	-.8946	-.1313
	2006	.5201*	.11392	.000	.1638	.8764
	2007	.2194	.07087	.056	-.0022	.4411
	2008	.1110	.07546	1.000	-.1250	.3470
2011	2009	.3723*	.08369	.000	.1106	.6340
	2010	.2214*	.06734	.029	.0108	.4320
	2012	.1301	.11348	1.000	-.2248	.4850
	2013	-.2915	.12742	.623	-.6900	.1070
	2006	.3900	.14135	.164	-.0521	.8321
	2007	.0893	.10966	1.000	-.2536	.4323
	2008	-.0191	.11268	1.000	-.3715	.3333
2012	2009	.2422	.11835	1.000	-.1279	.6123
	2010	.0913	.10741	1.000	-.2446	.4272
	2011	-.1301	.11348	1.000	-.4850	.2248
	2013	-.4216	.15244	.160	-.8984	.0551
	2006	.8116*	.15277	.000	.3338	1.2894
	2007	.5109*	.12403	.001	.1230	.8988
	2008	.4025*	.12671	.042	.0062	.7987
2013	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

The error term is Mean Square(Error) = .984.

*. The mean difference is significant at the

Chapter 4

Table 1

Imputation Number		class_type_274	N	Mean	Std. Deviation	Std. Error Mean
Original data	hs_gpa	1	1634	3.7029	.36826	.00911
		0	1646	3.7231	.35654	.00879
	act_engl	1	1554	25.18	4.502	.114
		0	1584	25.71	4.717	.119
	act_math	1	1554	28.09	3.649	.093
		0	1583	28.44	3.815	.096
	act_cmpst	1	1554	26.65	3.490	.089
		0	1586	27.05	3.734	.094
	sat_vrbl	1	206	570.24	104.272	7.265
		0	222	597.84	94.934	6.372
	sat_math	1	206	643.69	78.057	5.438
		0	222	663.74	79.972	5.367
	sat_comb	1	206	1213.94	158.370	11.034
		0	222	1261.58	156.586	10.509
1	hs_gpa	1	1804	3.6965	.36780	.00866
		0	1788	3.7217	.35780	.00846
	act_engl	1	1804	25.10	4.588	.108
		0	1788	25.60	4.753	.112
	act_math	1	1804	28.06	3.718	.088
		0	1788	28.37	3.850	.091
	act_cmpst	1	1804	26.59	3.572	.084
		0	1788	26.98	3.730	.088
	sat_vrbl	1	1804	582.51	38.117	.897
		0	1788	586.52	36.681	.867
	sat_math	1	1804	653.10	27.805	.655
		0	1788	655.15	29.534	.698
	sat_comb	1	1804	1235.61	55.146	1.298
		0	1788	1241.67	56.843	1.344
2	hs_gpa	1	1804	3.6976	.37056	.00872
		0	1788	3.7191	.35816	.00847
	act_engl	1	1804	25.12	4.532	.107

Table 1 continued

		0	1788	25.62	4.734	.112
	act_math	1	1804	28.05	3.701	.087
		0	1788	28.36	3.858	.091
	act_cmpst	1	1804	26.62	3.541	.083
		0	1788	26.97	3.739	.088
	sat_vrbl	1	1804	583.02	38.415	.904
		0	1788	586.35	36.673	.867
	sat_math	1	1804	652.87	27.841	.655
		0	1788	655.26	29.527	.698
	sat_comb	1	1804	1235.89	55.292	1.302
		0	1788	1241.62	56.766	1.342
	hs_gpa	1	1804	3.6986	.36780	.00866
		0	1788	3.7210	.35651	.00843
	act_engl	1	1804	25.05	4.560	.107
		0	1788	25.57	4.730	.112
	act_math	1	1804	28.04	3.655	.086
		0	1788	28.36	3.870	.092
3	act_cmpst	1	1804	26.53	3.533	.083
		0	1788	26.94	3.730	.088
	sat_vrbl	1	1804	582.54	38.399	.904
		0	1788	586.85	36.654	.867
	sat_math	1	1804	652.73	27.815	.655
		0	1788	655.05	29.462	.697
	sat_comb	1	1804	1235.27	55.297	1.302
		0	1788	1241.91	56.828	1.344
	hs_gpa	1	1804	3.7042	.37038	.00872
		0	1788	3.7203	.35780	.00846
	act_engl	1	1804	25.11	4.568	.108
		0	1788	25.55	4.759	.113
	act_math	1	1804	28.08	3.675	.087
		0	1788	28.35	3.873	.092
	act_cmpst	1	1804	26.59	3.566	.084
4		0	1788	26.94	3.746	.089
	sat_vrbl	1	1804	582.65	38.231	.900
		0	1788	585.90	36.575	.865
	sat_math	1	1804	652.84	27.771	.654

Table 1 continued

		0	1788	655.32	29.506	.698
	sat_comb	1	1804	1235.48	55.234	1.300
		0	1788	1241.22	56.842	1.344
5	hs_gpa	1	1804	3.6990	.36901	.00869
		0	1788	3.7190	.35631	.00843
	act_engl	1	1804	25.09	4.566	.107
		0	1788	25.58	4.779	.113
	act_math	1	1804	28.03	3.729	.088
		0	1788	28.33	3.879	.092
	act_cmpst	1	1804	26.59	3.548	.084
		0	1788	26.94	3.768	.089
	sat_vrbl	1	1804	583.01	38.368	.903
		0	1788	585.84	36.685	.868
	sat_math	1	1804	653.05	27.846	.656
		0	1788	655.36	29.507	.698
	sat_comb	1	1804	1236.06	55.313	1.302
		0	1788	1241.19	56.832	1.344
Pooled	hs_gpa	1	1804	3.6992		.00927
		0	1788	3.7202		.00855
	act_engl	1	1804	25.09		.112
		0	1788	25.58		.117
	act_math	1	1804	28.05		.089
		0	1788	28.36		.093
	act_cmpst	1	1804	26.58		.091
		0	1788	26.96		.092
	sat_vrbl	1	1804	582.75		.943
		0	1788	586.29		.985
	sat_math	1	1804	652.92		.676
		0	1788	655.23		.711
	sat_comb	1	1804	1235.66		1.346
		0	1788	1241.52		1.385

Table 2

Group Statistics

Imputation Number		class_type _274	N	Mean	Std. Deviation	Std. Error Mean	Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
Original data	crse_grade _274	1	1804	3.2449	.79163	.01864			
		0	1788	3.1342	.83978	.01986			
1	crse_grade _274	1	1804	3.2449	.79163	.01864			
		0	1788	3.1342	.83978	.01986			
2	crse_grade _274	1	1804	3.2449	.79163	.01864			
		0	1788	3.1342	.83978	.01986			
3	crse_grade _274	1	1804	3.2449	.79163	.01864			
		0	1788	3.1342	.83978	.01986			
4	crse_grade _274	1	1804	3.2449	.79163	.01864			
		0	1788	3.1342	.83978	.01986			
5	crse_grade _274	1	1804	3.2449	.79163	.01864			
		0	1788	3.1342	.83978	.01986			
Pooled	crse_grade _274	1	1804	3.2449		.01864	.000	.000	1.000
		0	1788	3.1342		.01986	.000	.000	1.000

Table 3

Imputation Number			Levene's Test for Equality of Variances		t-test for Equality of Means						
			F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
										Lower	Upper
Original data	crse_grade_274	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
1	crse_grade_274	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
2	crse_grade_274	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
3	crse_grade_274	Equal variances assumed	9.625	.002	4.063	3590	.000	.11063	.02723	.05724	.16401

Table 3 continued

		Equal variances not assumed			4.062	3573.539	.000	.11063	.02724	.05723	.16403
4	crse_grade_274	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
5	crse_grade_274	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
Pooled	crse_grade_274	Equal variances assumed			4.063	.	.000	.11063	.02723	.05726	.16400
		Equal variances not assumed			4.062	.	.000	.11063	.02724	.05725	.16401

Table 4

Imputation Number		class_type_274	N	Mean	Std. Deviation	Std. Error Mean
Original data	crse_grade_324	1	1804	2.5732	1.18706	.02807
		0	1788	2.4888	1.19403	.02811
1	crse_grade_324	1	1804	2.5732	1.18706	.02807
		0	1788	2.4888	1.19403	.02811
2	crse_grade_324	1	1804	2.5732	1.18706	.02807
		0	1788	2.4888	1.19403	.02811
3	crse_grade_324	1	1804	2.5732	1.18706	.02807
		0	1788	2.4888	1.19403	.02811
4	crse_grade_324	1	1804	2.5732	1.18706	.02807
		0	1788	2.4888	1.19403	.02811
5	crse_grade_324	1	1804	2.5732	1.18706	.02807
		0	1788	2.4888	1.19403	.02811
Pooled	crse_grade_324	1	1804	2.5732		.02807
		0	1788	2.4888		.02811

Figure 1

Imputation_ Imputation Number = Original data

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of crse_grade_324 is the same across categories of class_type_274.	Independent-Samples Mann-Whitney U Test	.022	Reject the null hypothesis.

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

Imputation_ Imputation Number = 1

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of crse_grade_324 is the same across categories of class_type_274.	Independent-Samples Mann-Whitney U Test	.022	Reject the null hypothesis.

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

Figure 1 continued

Imputation_ Imputation Number = 2

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of crse_grade_324 is the same across categories of class_type_274.	Independent-Samples Mann-Whitney U Test	.022	Reject the null hypothesis.

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

Imputation_ Imputation Number = 3

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of crse_grade_324 is the same across categories of class_type_274.	Independent-Samples Mann-Whitney U Test	.022	Reject the null hypothesis.

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

Figure 1 continued

Imputation_ Imputation Number = 4

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of crse_grade_324 is the same across categories of class_type_274.	Independent-Samples Mann-Whitney U Test	.022	Reject the null hypothesis.

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

Imputation_ Imputation Number = 5

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of crse_grade_324 is the same across categories of class_type_274.	Independent-Samples Mann-Whitney U Test	.022	Reject the null hypothesis.

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

Table 5

Tests of Between-Subjects Effects

Dependent Variable: crse_grade_324

Imputation Number	Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
	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
	crse_grade_274	1217.356	1	1217.356	1139.404	.000	.241	1139.404	1.000
Original data	major	19.491	7	2.784	2.606	.011	.005	18.243	.899
	class_type_274	22.363	1	22.363	20.931	.000	.006	20.931	.996
	gender	.342	1	.342	.320	.571	.000	.320	.087
	Error	3825.992	3581	1.068					
	Total	28101.858	3592						
	Corrected Total	5094.997	3591						
1	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
	crse_grade_274	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
	class_type_274	22.363	1	22.363	20.931	.000	.006	20.931	.996
	gender	.342	1	.342	.320	.571	.000	.320	.087
	Error	3825.992	3581	1.068					
	Total	28101.858	3592						

Table 5 continued

	Corrected Total	5094.997	3591						
	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
	crse_grade_274	1217.356	1	1217.356	1139.404	.000	.241	1139.404	1.000
2	major	19.491	7	2.784	2.606	.011	.005	18.243	.899
	class_type_274	22.363	1	22.363	20.931	.000	.006	20.931	.996
	gender	.342	1	.342	.320	.571	.000	.320	.087
	Error	3825.992	3581	1.068					
	Total	28101.858	3592						
	Corrected Total	5094.997	3591						
	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
	crse_grade_274	1217.356	1	1217.356	1139.404	.000	.241	1139.404	1.000
3	major	19.491	7	2.784	2.606	.011	.005	18.243	.899
	class_type_274	22.363	1	22.363	20.931	.000	.006	20.931	.996
	gender	.342	1	.342	.320	.571	.000	.320	.087
	Error	3825.992	3581	1.068					
	Total	28101.858	3592						
	Corrected Total	5094.997	3591						
4	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
	crse_grade_274	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

Table 5 continued

.

	class_type_274	22.363	1	22.363	20.931	.000	.006	20.931	996
	gender	.342	1	.342	.320	.571	.000	.320	.087
	Error	3825.992	3581	1.068					
	Total	28101.858	3592						
	Corrected Total	5094.997	3591						
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
	crse_grade_274	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
	class_type_274	22.363	1	22.363	20.931	.000	.006	20.931	.996
	gender	.342	1	.342	.320	.571	.000	.320	.087
	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

APPENDIX B. INSTITUTIONAL REVIEW BOARD APPROVAL

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: 10/5/2012

To: Anne (Peggy) Boylan-Ashraf
2245 Howe Hall

CC: Dr. Steven Freeman
104 I ED II

From: Office for Responsible Research

Title: Redesigning Engineering Courses

IRB ID: 12-415

Study Review Date: 10/4/2012

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.

- (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified directly or through identifiers linked to the subjects.

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.

Please be aware that **approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **An IRB determination of exemption in no way implies or guarantees that permission from these other entities will be granted.**

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

IRB ID: 12-415

INSTITUTIONAL REVIEW BOARD (IRB)

Exempt Study Review Form

RECEIVED
AUG 21 2012
By IRB

Title of Project: Redesigning Engineering Courses			
Principal Investigator (PI): **Anne (Peggy) Boylan-Ashraf**			Degrees: B.S, M.S
University ID: **735 248 514**	Phone: (515) 708-6623	Email Address: peggyba@iastate.edu	
Correspondence Address: 2245 Howe Hall			
Department: Agricultural and Biosystems Engineering		College/Center/Institute: Engineering, ISU	
PI Level: ☐ Tenured, Tenure-Eligible, & NTER Faculty ☐ Adjunct/Affiliate Faculty ☐ Collaborator Faculty ☐ Emeritus Faculty ☐ Visiting Faculty/Scientist ☒ Senior Lecturer/Clinician ☐ Lecturer/Clinician, w/Ph.D. or DVM ☐ P&S Employee, P37 & above ☐ Extension to Families/Youth Specialist ☐ Field Specialist III ☐ Postdoctoral Associate ☐ Graduate/Undergrad Student ☐ Other (specify:)			

FOR STUDENT PROJECTS *(Required when the principal investigator is a student)*			
Name of Major Professor/Supervising Faculty: Steve Freeman			
University ID: 735 248 514	Phone: (515) 708-6623	Email Address: peggyba@iastate.edu	
Campus Address: 2245 Howe Hall		Department: Agricultural and Biosystems Engineering	
Type of Project: (check all that apply)	☒ Thesis/Dissertation	☐ Class Project	☐ Other (specify:)

Alternate Contact Person: Steve Freeman	Email Address: sfreeman@iastate.edu
Correspondence Address: 106 I Ed II	Phone: (515) 294-1123

ASSURANCE

- I certify that the information provided in this application is complete and accurate and consistent with any proposal(s) submitted to external funding agencies. Misrepresentation of the research described in this or any other IRB application may constitute non-compliance with federal regulations and/or academic misconduct.
- I agree to provide proper surveillance of this project to ensure that the rights and welfare of the human subjects are protected. I will report any problems to the IRB. See Reporting Adverse Events and Unanticipated Problems for details.
- I agree that modifications to the approved project will not take place without prior review and approval by the IRB.
- I agree that the research will not take place without the receipt of permission from any cooperating institutions, when applicable.
- I agree to obtain approval from other appropriate committees as needed for this project, such as the IACUC (if the research includes animals), the IBC (if the research involves biohazards), the Radiation Safety Committee (if the research involves x-rays or other radiation producing devices or procedures), etc.
- I understand that approval of this project does not grant access to any facilities, materials or data on which this research may depend. Such access must be granted by the unit with the relevant custodial authority.
- I agree that all activities will be performed in accordance with all applicable federal, state, local, and Iowa State University policies.

8/17/2012 — Signature of Principal Investigator, Date

8/17/12 — Signature of Major Professor/Supervising Faculty, Date
(Required when the principal investigator is a student)

- I have reviewed this application and determined that departmental requirements are met, the investigator(s) has/have adequate resources to conduct the research, and the research design is scientifically sound and has scientific merit.

8/20/12 — Signature of Department Chair, Date

For IRB Use Only	☐ Not Research Per Federal Regulations	☐ No Human Participants	Review Date: 9/4/2012
	☒ Minimal Risk	EXEMPT Per 45 CFR 46.101(b): 1, 2, 4 (NE)	
IRB Reviewer's Signature			

Exempt Study Information

Please provide *Yes* or *No* answers, except as specified. Incomplete forms will be returned without review.

Part A: Key Personnel

List all members and relevant qualifications of the project personnel. Key personnel includes the principal investigator, co-principal investigators, supervising faculty member, and any other individuals who will have contact with the participants or the participants' data (e.g., interviewers, transcribers, coders, etc.). This information is intended to inform the committee of the training and background related to the specific procedures that each person will perform on the project. For more information, please see Human Subjects - Persons Required to Obtain IRB Training.

NAME	Interpersonal contact or communication with subjects, or access to private identifiable data?	Involved in the consent process?	Contact with human blood, specimens, or other biohazardous materials?	Other Roles in Research	Qualifications (i.e., special training, degrees, certifications, coursework, etc.)	Human Subjects Training Date
Anne (Peggy) Boylan-Ashraf	☒	☒	☐			8/16/2012
Steve Freeman	☒	☒	☐	Supervisor of graduate program		7/20/2000
	☐	☐	☐			
	☐	☐	☐			
	☐	☐	☐			
	☐	☐	☐			
	☐	☐	☐			
	☐	☐	☐			
	☐	☐	☐			
	☐	☐	☐			
	☐	☐	☐			
	☐	☐	☐			
	☐	☐	☐			
	☐	☐	☐			
	☐	☐	☐			
	☐	☐	☐			

Part B: General Overview

Please provide a brief summary of the purpose of your study:
The purpose of this study is to investigate whether there is a difference in student performance and attendance between the traditional 50-minute, three times a week class and the redesigned class, which will involve interventions using quasi-interactive videos and interactive teaching style and on focusing on desired learnings. A comparison is designed to focus on several areas of progress, which include students' examinations, students' homework, students' final class grade.

Please provide a brief summary of your research design:
A cross sectional and ex-post facto study will be carried out on two groups of participants: 1) undergraduate students at Iowa State University who will be enrolled in the traditional Statics of Engineering class in fall 2012 and spring 2013 and 2) undergraduate students at Iowa State University who will be enrolled in the redesigned Statics of Engineering class in fall 2012 and spring 2013. This study will employ a non-experimental, descriptive, and correlational research design to understand the outcome of student learning effectiveness concerning the impact of learning intervention on their academic learning and to investigate the influence of these factors on students' academic success. Quantitative data collection will be employed which will allow the data to be quantified and analyzed using statistical analysis. To ensure confidentiality, I will build my dataset using student identification numbers, however, as soon soon as the dataset is ready, all student identifiers will be removed prior to any analysis and that any results presented will be presented in aggregate form such that no individuals can be identified. This ensures that the investigators in this project cannot identify the individuals to whom the data pertain.

Part C: Exemption Categories

☒Yes	☐No	1.	Are you conducting research on Educational Practices (e.g., instructional techniques, curriculum effectiveness, etc.)? If *Yes*, please answer questions 1a through 1e. If *No*, please proceed to question 2.
☒Yes	☐No	1a.	Will the research be conducted in an established or commonly accepted educational setting, such as a classroom, school, professional development seminar, etc.?
☐Yes	☒No	1b.	Will the research be conducted in any settings that would **not** generally be considered to be established or commonly accepted educational settings? If *Yes*, please specify:
☒Yes	☐No	1c.	Will the research procedures and activities involve normal educational practices (e.g., activities that normally occur in the educational setting)? Examples include research on regular or special education instructional strategies or the effectiveness of instructional techniques, curricula, or classroom management methods.

☐ Yes ☒ No **1d.** Will the research procedures include anything **other than** normal educational practices? *If Yes*, please specify: _____

☐ Yes ☒ No **1e.** Will the procedures include randomization into different treatments or conditions, radically new instructional strategies, or deception of subjects? *If Yes*, please specify: _____

☒ Yes ☐ No **2. Does your research involve use of educational tests, survey procedures, interview procedures, or observations of public behavior? If *Yes*, please answer questions 2a through 2c. If *No*, please proceed to question 3.**

☐ Yes ☐ No **2a.** Will the research involve one or more of the following? (Check all that apply.)

☒ The use of educational tests (cognitive, diagnostic, aptitude, achievement)
☐ Surveying or interviewing adults
☐ Observations of public behavior* of adults
☐ Observations of public behavior* of children, when the researcher will not interact or intervene with the children

*Note: Activities occurring in the workplace and school classrooms are not generally considered to involve public behavior.

☐ Yes ☒ No **2b.** Are **all** of the participants elected or appointed public officials or candidates for public office?

☒ Yes ☐ No **3. Does the research involve the collection or study of *currently existing* data, documents, records, pathological specimens, or diagnostic specimens? If *Yes*, please answer questions 3a through 3c. If *No*, please proceed to question 4.**

☐ Yes ☒ No **3a.** Are **all** of the data, documents, records, or specimens **publicly** available?

☐ Yes ☒ No **3c.** Will the data you record for your study include ID codes? *If Yes*, please answer 3ci and 3cii.

☐ Yes ☐ No **3ci.** Does a "key" exist linking the ID codes to the identities of the individuals to whom the data pertains?

☐ Yes ☐ No **3cii.** Will any persons on the research team have access to this key?

☐ Yes ☒ No **4. Does your research involve Taste and Food Quality tests and Consumer Acceptance Studies involving food? If *Yes*, please answer questions 4a through 4c. If *No*, please proceed to question 5.**

☐ Yes	☐ No	4a.	Is the food to be consumed normally considered wholesome, such as one would find in a typical grocery store?
☐ Yes	☐ No	4b.	If the food contains additives, are the additives at or below the level normally considered to be safe by the FDA, EPA or Food Safety and Inspection Service of USDA? Consider additives in commercially available foods found at a grocery store and/or any additives that are added to food for research purposes.
☐ Yes	☐ No	4c.	If there are agricultural chemicals or environmental contaminants in the food, are they at or below the level found to be safe by the FDA, EPA or Food Safety and Inspection Service of USDA?

☐ Yes	☒ No	5.	**Is your study a research or demonstration project to examine** • **Federal** public benefit or service programs such as Medicaid, unemployment, social security, etc.; or • Procedures for obtaining benefits or service under these programs; or • Possible changes in or alternatives to those programs or procedures; or • Possible changes in methods or levels of payment for benefits or services under these programs?
☐ Yes	☐ No	5a.	If Yes, is the research or demonstration project pursuant to specific federal statutory authority?

Part C: Additional Information

☐ Yes ☒ No **6. Does your research involve any procedures that do not fit into one or more of the categories in items #1–#5 listed above, such as the following? (Check all that apply.)**

- ☐ Usability testing of websites, software, devices, etc.
- ☐ Collection of information from private records when identifiers are recorded
- ☐ Procedures conducted to induce stress, moods, or other psychological or physiological reactions
- ☐ Presentation of materials typically considered to be offensive, threatening, or degrading
- ☐ Video recording or photographing non-public behaviors
- ☐ Use of deception (e.g., misleading participants about the procedures or purpose of the study)
- ☐ Physical interventions, such as
  - ☐ blood draws
  - ☐ new collection of biological specimens
  - ☐ use of physical sensors (ECG, EKG, EEG, ultrasound, etc.)
  - ☐ exercise, muscular strength assessment, flexibility testing
  - ☐ body composition assessment
  - ☐ measuring of height and weight
  - ☐ x-rays
  - ☐ changes in diet or exercise
- ☐ Tests of sensory acuity (i.e., vision or hearing tests, olfactory tests, etc.)
- ☐ Consumption of food (other than as described in #4) or dietary supplements
- ☐ Clinical studies of drugs or medical devices
- ☐ Other; please specify: _____

☐ Yes ☐ No 6a. If *Yes*, is your research conducted in an established educational setting, **and** are the checked procedures part of normal educational practices given that setting? If *Yes*, please describe:

_____

☐ Yes ☒ No **7. Do you intend or is it likely that your study will include any persons from the following populations? (Check all that apply.)**

- ☐ Prisoners
- ☐ Cognitively impaired
- ☐ Children (persons under age 18)
- ☐ Wards of the State
- ☐ Persons who are institutionalized

7 a. If *Yes*, please describe how they will be involved and what procedures they will complete:

_____

☐ Yes ☒ No **8. Will any of the following identifiers be *linked to the data* at any time point during the research? (Check all that apply.)**

☐ Names: ☐ First Name Only ☐ Last Name Only ☐ First and Last Name
☐ Phone/fax numbers
☐ ID codes that can be linked to the identity of the participant (e.g., student IDs, medical record numbers, account numbers, study-specific codes, etc.)
☐ Addresses (email or physical)
☐ Social security numbers
☐ Exact dates of birth
☐ IP addresses
☐ Photographs or video recordings
☐ Other; please specify: _____

☐ Yes ☒ No **9. Is there a reasonable possibility that participants' identities could be ascertained from any combination of information in the data? If Yes, please describe: _____**

10. If Yes to either #8 or #9 above, please answer the following:

☒ Yes ☐ No **10a. Will participants' identities be kept confidential when results of the research are disseminated?**

☐ Yes ☒ No **10b. Could any of the information collected, if disclosed outside of the research, reasonably place the subjects at risk of any of the following? (Check all that apply.)**

☐ Criminal liability
☐ Civil liability
☐ Damage to the subjects' financial standing
☐ Damage to the subjects' employability
☐ Damage to the subjects' reputation

☐ Yes ☒ No **10c. Does the research, directly or indirectly, involve or result in the collection of any information regarding any of the following? (Check all that apply.)**

☐ Use of illicit drugs
☐ Criminal activity
☐ Child, spousal, or familiar abuse
☐ Mental illness
☐ Episodes of clinical depression
☐ Suicidal thoughts or suicide attempts
☐ Health history
☐ History of job losses
☐ Exact household income other than in general ranges
☐ Negative opinions about one's supervisor, workplace, teacher, or others to whom the subject is in a subordinate position
☐ Opinions about race, gender, sexual orientation, or any other socially sensitive or controversial topics
☐ Sexual preferences or behaviors
☐ Religious beliefs
☐ Any other information that is generally considered to be private or sensitive given the setting of your research; if so, please specify: _____

After completion of Parts A, B, and C of this application, please send the completed form to:

Institutional Review Board (IRB)
Office for Responsible Research
1138 Pearson Hall
Ames, IA 50011-2200

Data collection materials (e.g., survey instruments, interview questions, recruitment and consent documents, etc.) do not need to be submitted with this application.

If you have any questions or feedback, please contact the IRB office at IRB@iastate.edu or 515-294-4566.

IOWA STATE UNIVERSITY

Release of Student Information for Research Requests

Educational researchers may request access to confidential student information available through the Registrar and Enrollment Services data systems which are protected under the Federal Education Rights and Privacy Act (FERPA) http://www.registrar.iastate.edu/info/ferpanotice.html. Researchers may be provided information obtained from confidential files for research purposes if they comply with the following requirements for release:

1. If IRB approval is needed (e.g., if data contains personal identifiers or students will be contacted), the researcher shall provide a copy of the IRB approval letter to the Office of the Registrar prior to receiving access to the requested data.
2. The researcher shall describe the population for the study and the specific data elements requested, and provide an explanation of the research need for those data elements.
3. The researcher shall agree to reimburse the Office of the Registrar for the actual costs incurred in the collection of the data.
4. The researcher shall take every precaution to preserve the privacy of individual students and the confidentiality of the data.
5. Others seeking access to the data whose names are not listed below shall make a separate inquiry to the Office of the Registrar.
6. The data shall be stored in a secure way. Data may only be stored and accessed from university computers with only designated researchers having access.
7. Multiple copies of the data shall not be created.
8. Copies of the data shall not be maintained on external devices such as flash drives.
9. The data shall only be used for the specified research project and for no other purposes.
10. The data shall be destroyed by the date specified by the researcher: 08-01-2017 The Researcher shall inform the contact person listed below when the data has been destroyed.

If not already outlined in your IRB form, please describe the purpose of the study, explain your plan for maintaining student privacy, and provide a list of specific variables being requested (include separate attachments if needed):

See attached IRB form.

In question 3 in the IRB form, I am indicating student data, which I will be requesting from ISU's registrar's office. These data include **GPA**, **ACT/SAT** scores when they are available, and **final class grades**. I will be requesting GPA, ACT/SAT scores, and final class grades of students enrolled by section in EM 274 class between Fall 2006 through Fall 2012. I will also be requesting GPA, ACT/SAT scores, and final class grades of students enrolled by section in EM 324 class between Spring 2007 through Spring 2013 As soon as the data set is put together, I will remove students' identifiers and any code that did help me build my data base before I start my analysis; and until my data set is complete, all information regarding student identifiers will kept locked in the PI's office. Furthermore results will only be shared and published in aggregate form.

Primary Researcher Information:

Name: Anne (Peggy), Boylan-Ashraf, Christie

Department: Aerospace Engineering

Phone: 515-294-6086 E-mail: peggyba@iastate.edu

I agree to the terms above.

[signature] 9/27/2012

Signature of Primary Researcher — Date

[signature] 9/27/12

Signature of Major Professor (if primary researcher is a student) — Date

Signature of Additional Researcher — Date

Signature of Additional Researcher — Date

Signature of Additional Researcher — Date

Signature of Additional Researcher — Date

Signature of Additional Researcher — Date

Signature of Additional Researcher — Date

[signature] Oct. 1, 2012

Signature of University Registrar or Designee — Date

Information on page 3 is only contact information for the Registrar and Office for Responsible Research (ORR)