Comparing the effect of cooperative exams on student learning between an interactive lecture and a student-centered class

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Comparing the effect of cooperative exams on student learning between an interactive lecture and a student-centered class

by

Theresa Halligan

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Geology

Program of Study Committee:
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The student author, whose presentation of the scholarship herein was approved by the program of study committee, is solely responsible for the content of this thesis. The Graduate College will ensure this thesis is globally accessible and will not permit alterations after a degree is conferred.

Iowa State University
Ames, Iowa
2019

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ABSTRACT

In the 1960’s education research began to shift from behavioral learning theories to cognitive learning theories. This shift was driven by psychologists like Dewey, Piaget, and Vygotsky. Students were viewed as active participants in the learning process rather than passive learners. Research switched to how cognitive learning theories could be applied to education of students. This was the birth of active pedagogy. Current research is focused on comparing different active pedagogies. Recent research on student-centered classes and two-stage cooperative exams have shown positive effects in many fields. However, there is limited research on the effect in large (>100), introductory geology courses. This study is focused on the effect of changing from an interactive to a student-centered class with two-stage cooperative exams used in both settings. Students in consecutive fall semesters taught by the same professor were taught in an interactive pedagogy and then a student-centered pedagogy. Four exams were administered in each semester and kept the same between semesters for comparison. The student-centered class had significantly higher final grades compared to the interactive class. Within the student-centered class, male and STEM majors had significantly higher grades compared with female and non-STEM majors. Both classes show an increase in the retention of material from the first exam to the final exam. The student-centered class had significant improvement in normalized change scores from the beginning to the end of the semester and compared with the interactive class.
CHAPTER 1. CONSTRUCTIVISM - PHILOSOPHY OF LEARNING EDUCATION

Theoretical Background

Before the 1960’s, learning theory was dominated by the behavioral tradition illustrated by psychologists like Thorndike, Skinner, Hull, and Spence (e.g., Andre & Phye, 1986). Within behavioral learning theory the student was viewed as passively learning, reacting to external stimuli, and simply acquiring new associations into their learning (Andre & Phye, 1986). It is much like the student was being shaped and molded by outside forces. There was little discussion of the activities of the mind, such as: how is learning processed, how information is stored, and how information is retrieved.

By the early to mid-1960’s the cognitive learning theories of European psychologists such as Piaget and Vygotsky had shifted the field, dominating how education psychology was studied (Piaget, 1954; Vygotsky, 1962; Andre & Phye, 1986). There was a shift in emphasis toward seeing the learner as being active in their learning and restructuring of their mental frameworks (Piaget, 1954; Vygotsky, 1962; Andre & Phye, 1986). Work on the mind and how learning occurs became more central to educational psychology. Within educational psychology, instructors emphasised active mental exploration of topics and learner experience (Andre & Phye, 1986). The cognitive theories that were developed at that time fall into a larger group of constructivist learning. Constructivism emphasizes that students learn through building their own knowledge, connecting new facts and concepts to existing knowledge structures, bridging information between subjects, and using this to form new understanding (Bransford et al., 1999; Miller & Groccia, 1997; Beardsly, 1992).
This shift to cognitive theory was not sudden. Psychologists and academics had been working on cognitive learning theories for decades before it finally dominated the field (Dewey, 1938; Campbell, 1965). In the United States, Francis Parker, the superintendent in Quincy, Massachusetts, was one of the most successful advocates for cooperative learning in the second half of the 19th century (Campbell, 1965). Parker’s cooperative learning empowered students to be active participants in their learning (Campbell, 1965). He created cooperative, democratic classrooms with an emphasis on freedom and learning enthusiasm.

In the early 20th century, Dewey (1938) began writing about the need for a theory, or philosophy of education, for the new pedagogies that were being developed like cooperative learning. Dewey (1938) proposed that students learn best when they interact with their environment, advocating for experiential, or hands-on, learning. He was one of the most influential educational thinkers of the 20th century, and a supporter of the educational philosophy of pragmatism (Torbert, 1972).

Following Dewey’s experiential education approach, Piaget (1954) theorized that students develop and process their learning using a constructivist approach. Piaget’s work focused mainly on the development of young students, but the principles of his work can have a wider application to education (Piaget, 1954; Ginsburg, 1985). The focus on concrete activity driving learning led to misinterpretations of Piaget’s work, and the belief that active learning requires physical activities (Ginsburg, 1985). Instead, Piaget encouraged active engagement in the learning process, whether it was in physical activity, reflection, or socialization (Woolfolk & McCune-Nicolich, 1980; Ginsburg, 1985).
A key part of the active learning aspect in Piaget’s theory involves cognitive conflict (Piaget, 1954; Ginsburg, 1985; Buchs et al., 2004; Webb, 2013; Stahl, 2013). He proposed that cognitive development is based on previous knowledge, and that new learning occurs when new knowledge conflicts with the previous one. His socio-cognitive conflict theory says that a student may find information that conflicts with their prior knowledge or they may have peers who disagree with their knowledge: these offer opportunities for students to reassess their knowledge, compare it with new information, and restructure their understanding of a topic (Piaget, 1954; Tudge, 1990; Buchs et al., 2004; Webb, 2013; Stahl, 2013). Alternatively, a student may find that their prior knowledge was correct and reinforce it by resolving the conflict. For socio-cognitive conflict theory to work, it is very important that students have an awareness of what they know. Without that conscious awareness, it is possible for students to not notice conflicts in new information, or to ignore it altogether (e.g., Webb, 2013).

While Piaget was a major advocate for active, constructivist learning he also recognized that some ‘rote learning’ was necessary in education (Ginsburg, 1985). There are portions of education that require simple memorization, such as names, vocabulary, and rules. Piaget even admitted that the lecture-style learning can be effective for this type of rote learning, if not for deeper contextual learning (Ginsburg, 1985).

A different approach to constructivist learning emphasizes the importance of the social context for a student’s cognitive growth, either through interactions between teacher and student or among students (Vygotsky, 1962). Vygotsky’s socio-cultural theory contends that the cognitive growth of students relies on social processes and interactions with other people (e.g., Vygotsky, 1962; Jennings and Di, 1996; Webb, 2013, Stahl, 2013). Vygotsky’s perspective is quite similar to Piaget’s socio-cognitive conflict theory, but instead of emphasizing conflict as
the driving force for learning, the emphasis is on the tight relationship of social processes with cognitive development.

Vygotsky described socialization as a zone of proximal development, the space between a student’s actual knowledge and independent ability, and the potential knowledge and ability that can be achieved with the support of instructors or fellow students (Vygotsky, 1962; Tudge, 1990; Jennings and Di, 1996; Webb, 2013). He hypothesized that what students can do with cooperation today, they can do on their own tomorrow. Students working cooperatively in groups bridge the zone of proximal development (Tudge, 1990). Different students, who each may have pieces of knowledge that their fellows are missing, help to lay the path from the actual knowledge to the potential knowledge state. This cooperative learning is most effective when students discuss their process of getting to an answer instead of simply relaying the answer (Tudge, 1990; Jennings and Di, 1996; Webb, 2013). It is this discussion of process at the beginner level that can help guide other beginners in the field of knowledge.

Confidence and competence also play key roles in the zone of proximal development (Tudge, 1990). A competent, but not confident, student paired with a less competent student can result in a regression in knowledge. The less competent students may still show improvement, even when their partner showed regression. When a confident and competent student is paired with a less competent student, they are less likely to show this regression.

The instructor also plays an important role in bridging the zone of proximal development: instead of simply supplying explicit directions or answers, they can ask probing questions or give thoughtful hints to help the students construct their own knowledge (Vygotsky, 1962; Dixon-Krauss, 1996). Feedback, either from instructors or material, helps improve student learning for both competent and less competent students (Tudge, 1990).
Psychologists have been working on the concept of memory since the early 20th century (e.g., Baddeley, 1986; Andrade, 2001). For example, William James described primary and secondary memory, with primary being a temporary memory storage and secondary being a permanent storage (James, 1918; Baddeley, 1986; Andrade, 2001). Research into memory expanded in the mid-20th century with the development of computer language and information processing theory (Andre & Phye, 1986). British psychologists Atkinson and Shiffrin redefined memory using a modal model (Baddeley, 1986). The model had three parts: first a set of sensory buffers that accept information, then short term memory, a limited capacity, for temporary storage, and finally long term memory, an unlimited and relatively permanent storage (Baddeley, 1986; Andrade, 2001). The probability of information being transferred to long term memory from short term memory was described as a direct function of how much time it spent in the short-term memory.

This modal model began to run into trouble in the 1970’s as research showed it did not sufficiently explain memory and learning (Baddeley, 1986). Several studies found that keeping information exposed in the short-term memory for longer time did not result in long term learning of the information (Baddeley, 1986). Research into patients with short term memory damage found that they were capable of living active, normal lives. In the modal model they should not have been able to increase their long-term learning if the damaged short term memory was processing information (Baddeley, 1986).

The concept of working memory was developed in the late 1970’s and early 1980’s as an alternative to short-term memory (Baddeley, 1986; Andrade, 2001). Research showed that short-term memory could process information as well as store information. Baddeley and Hitch described this as the working memory, a workspace that could be broken up into parts (Baddeley
& Hitch, 1974; Baddeley, 1986; Andrade, 2001). The storage component was called the ‘phonological loop’, a short-term storage of auditory information, and the processing system as the central executive (Baddeley, 1986; Andrade, 2001). A visuo-spatial sketchpad was later added to the working memory theory for the short-term storage and manipulation of visual information (Baddeley, 1986).

Work on education psychology continued to develop into the mid to late 20th century with the refinement of information processing theory and modal model (Andre & Phye, 1986). Cognitive information-processing (CIP) theory draws inspiration in part from the rise of computer science, using concepts from it to explain the human mind’s ability to learn, remember, and use knowledge (Andrew & Phye, 1986). The CIP theory combines concepts from the older behavioral learning theory and the cognitive learning theory. Behavioral learning emphasises the environment and the instructor as the source of learning, while cognitive learning theory emphasises the mind and the student as the source of learning (Andrew & Phye, 1986). In the CIP theory learning occurs from both the previous experience and how the student acts and responds to the environment. Because it is so broad, it can be applied to a variety of theoretical perspectives. Where CIP theory is fundamentally different is in describing how information is processed by students (Andre & Phye, 1986).

Each step of mental operation during learning is described in CIP theory. Information is first processed and stored by the sensory memory (Bruning et al., 2011). It is then transferred to the temporary working memory, which is based on Baddeley’s theory for working memory (Baddeley, 1986; Bruning et al., 2011). Here the executive control processes incoming information, storing it either in the phonological loop or the visuo-spatial sketchpad (Bruning et
al., 2011). The executive control also transfers information to long-term memory and processes searches for information from long-term memory.

Despite the decades of research into how students learn and how to learn more effectively, more than 50% of all undergraduate geoscience classes are still taught in the didactic pedagogy (Stains et al., 2018). More than 50% of those taught using constructivist principles are in small (0-50) or medium (51-100) sized classes. There is a need for more research on large (>100) undergraduate geoscience classes implementing constructivist principles in the teaching pedagogy.

There are a variety of modern active learning techniques used in classrooms. Well known active learning techniques include jigsaw activities, think-pair-share, team-based learning, and peer instruction (e.g., McConnell et al., 2017).

Jigsaw activities have individual students become ‘experts’ of a small sample of information and then join up in groups with other ‘experts’ to share knowledge and build deeper conceptual understanding of topics (e.g., Tewksbury, 1995; McConnell et al., 2017).

In think-pair-share activities students are given a prompt by the instructor. They consider their answer individually, discuss their response with a classmate, and then share their answer with the rest of the class (Yuretich et al., 2001; Brame, 2016; McConnell et al., 2017).

Team-based learning is a form of structured peer learning where students work with a set team for the course of the semester (Michaelsen et al., 2004; Artz et al., 2016). Students build communication and teamwork skills while working to solve complex problems in these groups.

Peer instruction is one of the most widely used active learning teaching strategies in STEM disciplines (e.g., McConnell et al., 2017). Since this approach is central to the pedagogy that I am assessing, I am discussing it more in detail. Peer instruction was first described by Eric
Mazur, a physics professor at Harvard (Mazur, 1997). This method of active learning uses student interactions to focus students’ attention and learning on concepts instead of memorization.

Despite the variety of active learning techniques, large introductory classrooms are most likely to use didactic pedagogy (Stains et al., 2018). Future research needs to focus on integrating active learning into these classrooms and analyzing the effectiveness of different active learning techniques on student success.

References


CHAPTER 2. COMPARING THE EFFECT OF COOPERATIVE EXAMS ON STUDENT LEARNING BETWEEN AN INTERACTIVE LECTURE AND A STUDENT-CENTERED CLASS

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Abstract

Recent research on student-centered, or flipped, classes and two-stage cooperative exams have shown positive effects in many fields. However, there is limited research on the effect in large, introductory geology courses. This study is focused on the effect of changing from an interactive to a student-centered class with two-stage cooperative exams used in both settings. Students self-selected into the courses, which were offered in consecutive fall semesters and taught by the same instructor; at the beginning of the semester there were 220 students in the interactive class and 233 in the student-centered class. Analysis of gender, major, and school year indicated that the two semesters have similar populations. Four exams were administered in each semester and kept the same between semesters for comparison. Our results show that the student-centered class has significantly better final grades. Male students and STEM majors show significantly higher final grades in the student-centered class. Both classes show an increase in the retention of material from the first exam to the final exam. The student-centered
class had significant improvement in normalized change scores from the beginning to the end of
the semester and compared with the interactive class.

**Keywords**

Introductory Geology, Geology Education, Student-centered class

**Introduction**

Lecturing is the traditional way in which college-level science has been taught for over a
century (Stains et al., 2018). A large body of research (e.g., Mazur, 1997; Prince, 2004; Schell et
al., 2013; Boevé et al., 2017; Stains et al., 2018) shows that this approach is not effective at
engaging students in the content, and active learning has been advocated by national groups
focused on increasing science literacy across all levels (e.g., PCAST, 2012). Research shows that
non-science majors perform better in science courses when they are actively engaged, relating
better academic performance to increased attendance and self-efficacy (Mazur, 1997; Prince,
2004; Zipp, 2007; Brame, 2016; Thai et al., 2017; McConnell et al., 2017).

Despite this evidence, 55% of undergraduate science, technology, and math courses are
still taught by lecturing, 27% by lecturing with some forms of interactivity like clickers, and only
18% are fully student-centered (Stains et al., 2018). This is also true in the geosciences, with
more than 50% of the courses analysed by Stains et al. (2018) classified as didactic, and little
more than 25% as student-centered. However, there are few studies of student-centered
classrooms in large, introductory geology courses. Less than 50% of larger (>100) class sizes use
interactive or student-centered pedagogies (Stains et al., 2018).

Much of the research on active learning is based on social constructivist learning theory
(Dewey, 1938; Piaget, 1954; Vygotsky, 1962), combining the constructivist approach to learning
by interacting with the environment with the social interaction within groups of students.
Constructivism emphasizes that students learn through building their own knowledge,
connecting new facts and concepts to existing knowledge structures, bridging information among subjects, and using it to form new understanding (Bransford et al., 1999; Miller & Groccia, 1997; Beardsly, 1992). In particular, Vygotsky (1962) described a zone of proximal development: the space between a student’s actual knowledge and independent ability, and the potential knowledge and ability that can be achieved with the support of instructors or fellow students. In collaborative learning, students work in groups toward a common goal with emphasis on student interactions, and assessment is based on group work (Prince, 2004). Cooperative learning also involves students working in groups for a common goal, but here they are assessed individually. Some authors distinguish between collaborative and cooperative learning as being developed differently; however, both focus on student interaction instead of learning individually (Prince, 2004). In the context of this paper, the theoretical foundation of the course analysed in this study is based on cooperative learning.

There are various ways to implement cooperative learning in the classroom. Peer instruction is one of the most widely used active-learning teaching strategies in STEM disciplines, and the one adopted in the course we analysed (e.g., Mazur, 1997; McConnell et al., 2017). It utilises student interactions to focus students’ attention and learning on concepts instead of memorization. Peer instruction utilizes the ConcepTest approach: first the instructor gives a short lecture about a key point followed by a short, conceptual question about the subject (Mazur, 1997; Crouch et al., 2007; McConnell et al., 2017). Students respond first to the question individually. Responses can be recorded in a variety of ways, and the methods have evolved with technology: raised hands, flashcards, classroom response systems (clickers), Learning Catalytics (Mazur, 1997; McConnell et al., 2006, 2017; Crouch et al., 2007; Schell et al., 2013) or other student response systems (Prud’homme-Generaux, 2017). After responding,
students are not shown the correct answer to the question. Instead, they discuss or debate their answers with neighbors and answer the question a second time. This is also where students are engaging in cooperative, social learning (McConnell et al., 2006, 2017; Stoltzfus, 2016). These discussions allow students to formulate their ideas in their own words, think through arguments, and provide them with a way to judge their own understanding of the concept (Mazur, 1997; Crouch et al., 2007).

Peer instruction breaks up the monotony of lecturing, allows students to put their thoughts into their own words, increases problem-solving skills, understanding of concepts, and engagement. Peer instruction results in higher student grades, it creates social bonds, can correct misconceptions, and improves attitudes toward science (Mazur, 1997; McConnell et al., 2006, 2017; Crouch et al., 2007; Schell et al., 2013). It can be implemented relatively easily and can be used in classrooms of various sizes.

Two-stage cooperative exams are a form of pyramid exam where students first take the exam individually, then immediately retake it in groups of their choice, often with open notes, and their grade is a weighted total of the two attempts (Yuretich et al., 2001; Zipp, 2007; Knierim et al., 2015). The goal is to turn the exam from being only an assessment tool into a learning opportunity. By discussing answers students practice critical thinking, put ideas in their own words, and may prepare better because of social pressure (Yuretich et al., 2001; Zipp, 2007). Students show positive attitudes toward two-stage cooperative exams and value them as a learning tool (Yuretich et al., 2001). Research in large classrooms has shown that these exams can cause a significant increase in exam scores compared to classes using traditional exams or take home two-stage exams (Knierim et al., 2015). Students who were part of a group that answered a question correctly on an earlier exam were statistically more likely to answer that
question correctly on the final (Zipp, 2007). Recent research shows that lower-achieving students benefit the most from two-stage cooperative exams (Knierim et al., 2015).

The goal of this paper is to compare the effect of cooperative exams on student learning in an introductory physical geology course as the instruction transitioned from interactive lecture to student-centered. Our research questions are:

1. Do students perform progressively better in the individual component of cooperative exams? Our hypothesis is that there will be an increase in individual students’ performance in the exams following the first one.

2. Does content retention increase for material that is covered in multiple exams? Our hypothesis is that students will perform better in questions on material that was included in the previous exam(s).

3. Is there a significant difference in final grade between an interactive and a student-centered class? Is the difference the same for all students (lower-achieving, male/female, STEM/non-STEM, lower and upper-classmen)? We hypothesize that a student-centered class will show significantly higher final grades, and that the improvement will be true for all student groups.

Materials and Methods

Setting

Introductory physical geology is a popular freshman level course taught at most colleges and universities in the United States. Selected mostly by students seeking to fulfill the science requirement for the general education component of their degree, it enrolls students from a broad range of majors, as well as a small number of geology majors. The course described in this paper is offered both fall and spring semesters at a research-intensive public institution, and typically enrolls between 150 and 250 students. The class meets three times a week for 50-minute periods.
and is worth three credits. It has been taught each fall semester since 2001 by a tenured faculty, and has evolved from a traditional lecture format for the first 4 years to an interactive lecture format since 2005. In 2015 it was completely changed to a student-centered "flipped" format, a special type of “blended” classroom, with a combination of online and traditional learning (McNally et al., 2017; Thai et al., 2017).

The student-centered classroom can be broadly defined as a type of active learning pedagogy where class time is changed from lecturing to active learning and engagement, and where students learn content by completing pre-class activities (Stoltzfus, 2016; Boevé et al., 2017; Thai et al., 2017). These can include online videos of lectures, readings, and/or homework. In-class time is focused on working through more challenging problems, answering questions, and correcting misconceptions.

Instructors of large classes, or those whose appointment has a significant focus on research over teaching, may be reluctant to switch to a flipped classroom because of perceived difficulties and the time commitment (Stoltzfus, 2016; Stains et al., 2018). However, this classroom experience may offer a variety of incentives for student learning and development, especially for students with a low level of engagement or interest in the course content (Ryan & Reid, 2016; Stoltzfus, 2016; Thai et al., 2017).

The data collected in this study come from two sections; both taught by the same instructor in the 2014 and 2015 fall semesters. A second section was offered in both semesters: in 2014 it was taught by a temporary lecturer using the same material (syllabus, schedule, noted, quizzes, and exams) used in the first section. Both sections were taught in the same auditorium-style classroom with 252 fixed tablet-arm chairs organized in rows divided into a large central
and two smaller wing sections. In fall 2015 a different lecturer took over the second section and
developed it completely independently, except for the textbook and classroom.

The section in fall 2014 was taught with a constructivism pedagogy approach that
included a mixture of lectures broken up by active learning activities designed to be done in
groups, an approach that is identified as ‘interactive lecturing’ (Stains et al., 2018). Students
usually interacted only with the students seated next to them. In fall 2015, the class became
student-centered. Before each class period, students were required to complete their reading and
an online, MasteringGeology, homework assignment consisting of a variety of problems selected
by the instructor from the selection available as part of the textbook package. Students
would typically spend between 25 and 60 minutes on the homework alone, and their active time was
automatically recorded by the online learning platform. In class, students would answer
questions and work on problems created by the instructor using Learning Catalytics™, an online
tool designed for peer instruction and that runs on smartphones, tablets, or laptops. Students have
access to this tool through their purchased textbook package.

Cooperative, two-stage exams were used in both semesters with the same protocol:
students would spend 25 minutes completing a standard multiple-choice test consisting of 32-40
questions. They would then retake it using their own notes and usually working in groups of 2-6
students. The individual part of the exam was worth 75% of that exam grade; the group one 25%
. The instructor has used this style of exams since 2005. Each exam was cumulative, i.e. contained
content covered in the previous exams but not the same questions. This is designed to incentivize
the learning aspect of the group component (Yuretich et al., 2001).

Final grades were calculated by adding up three weighted assessment components, one
for exams, one for homework, and one for in-class work. There were three midterm and one final
exams, and each exam was worth 20% of the final grade. To accommodate possible absences and avoid the challenge to scheduling make-up exams, the lowest of the three midterm scores was dropped. In-class work provided another 20% of the final grade and homework the remaining 20%. Extra credit activities (surveys, additional homework, attendance at content-relevant public lectures, or acting as juror for the final project of an upper-level hydrogeology class (Bair, 2016)) can add up to 10% to the final percentage calculation. Grades were not curved.

**Study Population**

The institution where this course is taught is a research-intensive university in the U.S. midwest region with a fall 2014 enrollment of 28,893 and a fall 2015 enrollment of 30,034 undergraduate students. The average age of undergraduate students in both years was 20.6 and 43% of students were female.

Demographic information on the course was collected from the class list available to the instructor. In fall 2014, this section of physical geology enrolled 220 students (36% female and 64% male; 55% STEM majors, 41% non-STEM majors, and 4% undeclared students; 67% first- and second-year and 33% third- and fourth-year students). In fall 2015, there were 233 students (39% female and 61% male; 50% STEM majors, 47% non-STEM majors, and 3% undeclared students; 73% first- and second-year students and 27% third- and fourth-year students). The researchers of the student obtained permission from the Institutional Review Board (IRB) that reviews studies involving human subjects, and was given exempt status.

**Data and Statistical Methods**

To test the hypothesis that students do progressively better in each exam, we analysed data on all students who completed all four exams in each semester (fall 2014 $n=197$, fall 2015
Students’ exam scores were converted to normalized change scores (Marx and Cummings, 2007), calculated using a set of formulas depending on the post and pre-score difference (Eq. 1). To measure the progressive improvement of students, the pre-score was the individual attempt and the post-score the group attempt in the two-stage cooperative exams. These scores could then be compared within and between semesters using paired and independent t-tests with an $\alpha$ of 0.05. These normalized change scores also captured the changes in the zone of proximal development over the semester.

$$c = \begin{cases} \frac{\text{post} - \text{pre}}{100 - \text{pre}} & \text{post} > \text{pre} \\ \text{drop} & \text{post} = \text{pre} = 100 \text{ or } 0 \\ 0 & \text{post} = \text{pre} \\ \frac{\text{post} - \text{pre}}{\text{pre}} & \text{post} < \text{pre} \end{cases}$$

To test our hypothesis that content retention increases for material covered in multiple exams, we compared the percentage of correct plate tectonics answers from the final exam ($n=9$) with the first exam ($n=11$) from students’ individual attempts. Change in percentage of correct answers between semesters was analysed used paired t-tests with $\alpha$ of 0.05. Plate tectonics processes are included in the three learning outcomes identified for this physical geology course, and used to track students’ progress at the institutional level. Questions on this topic were included in all four exams.

For testing our hypothesis that the change in pedagogy increased the students’ final course grade, we analysed the scores of students who completed at least three exams: since the lowest of the three midterm grades is dropped, one missed exam did not affect a student’s final grade. Since the four exams used in the two semesters were kept the same, the two samples (fall 2014 $n=209$, fall 2015 $n=231$) were analysed to test the association of the teaching approach on the students’ final grade. Demographic information (gender, major, and year in college) were
used to analyse the two samples for independence using chi squared statistics. Final course grades were tested using one-way t-tests with an $\alpha$ of 0.05. Normality was assumed for all populations based on large sample size and the central limit theorem.

The effectiveness of the change in pedagogy was also tested using the final course grade in subpopulations within and between semesters. In fall 2014 there were 130 male and 79 female students; in fall 2015 there were 141 and 90, respectively. There were 114 STEM majors and 86 non-STEM majors in fall 2014; in fall 2015 there were 116 and 108, respectively. In fall 2014 there were 9 undecided majors and 7 in fall 2015; these students were not included in the major subpopulation.

Using the score in the individual attempt in the first exam, we identified students with a score <60%. To test if our study reproduces the results of Ryan and Reid (2016) that indicate lower-achieving students learn better in a student-centered class, we compared these two subpopulations (fall 2014 $n=60$, fall 2015 $n=86$). In fall 2014, this subgroup included 41.1% of students enrolled in the class, but only 26.0% in fall 2015.

To analyse possible causes for final course grade differences between the two semesters, unannounced in-class quizzes were used as a proxy for attendance and the total quiz, homework, and exam grades were independently calculated and analysed. Each student completed a percentage of the in-class quizzes, consisting of three to four questions, the same in both semesters, (fall 2014 $n = 7$, fall 2015 $n = 6$) and these were tested between the fall 2014 and 2015 classes using an independent t-test with an $\alpha$ of 0.05. Final grade was compared with the actual attendance (recalculated using in-class quizzes plus Learning Catalytics™ responses) in fall 2015 for each student to test for correlation.
Grades for quizzes, homework, and exams were calculated from the gradebook and compared with independent t-tests between the fall 2014 and 2015 classes. Homework in fall 2014 consisted of five homework assignments graded on completion. In fall 2015 the 33 homework assignments were delivered online via MasteringGeology and graded for correctness. Effect sizes for all significant results were calculated using Cohen’s $d$.

**Limitations**

Because of the university setting, it was not possible to set up a fully randomised experiment. The students self-select into courses and sections and represent a non-random population. We did not measure the incoming ability of the students, limiting comparisons to the results of the first midterm test. The comparisons were made between an interactive class and a student-centered class with some similarities in teaching methods.

**Results**

The two populations of students were tested for independence with a chi-squared test on the demographic variables of gender ($\chi^2 = 0.02, p = 0.879$), STEM/Non-STEM major ($\chi^2 = 0.96, p = 0.328$), and lower/upperclassmen ($\chi^2 = 1.99, p = 0.158$). The p-values for all three chi-squared tests were not significant, therefore, we cannot reject the null hypothesis that the differences in proportions of male vs. female, STEM vs. non-STEM major, and first and second vs. third and fourth year in college in each semester independent.

All data are reported as mean ± SE with $p$ values where appropriate and effect sizes for significant results calculated using Cohen’s $d$.

In fall 2014 there is an increase in the individual attempt scores from exam 1 and 2 vs exam 3 and the final (Fig. 1). Fall 2015 does not have the same increase in individual scores. Exam 1, 3, and the final are not significantly different, while exam 2 is significantly lower than the other exams (Fig. 1).
Normalized change scores of individual to group attempts on exams for fall 2014 did not show a statistically significant decrease from the first exam to the final exam (0.49 ± 0.02 vs. 0.59 ± 0.02, p = 1). In fall 2015 there was a statistically significant decrease in normalized change scores from the first exam to the final exam (0.47 ± 0.02 vs. 0.38 ± 0.02, p < 0.001, d = 0.31).
The normalized change score for exam 1 in both semesters was not significantly different (0.49 ± 0.02 vs. 0.47 ± 0.02). All other normalized change scores between fall 2014 and fall 2015 were significantly different, with fall 2015 having smaller normalized change scores (Fig. 2). Normalized change scores in fall 2014 showed an increasing trend over the course of the semester whereas fall 2015 showed a decreasing trend (Fig. 2).

In fall 2014, students answered correctly 83.80% of the plate tectonics questions in exam 1 (n=11), compared to 94.41% for plate tectonics questions in the final exam (n=9). In fall 2015 76.27% of plate tectonics questions were answered correctly in the first exam, compared to 87.29% in the final exam. There was no significant difference in the increase of percentage of
correct responses to plate tectonics questions (10.61 ± 1.25% vs. 11.02 ± 2.29%, p = 0.876).

Mean final grade for the fall 2015 class (n=231) was significantly higher than the mean final grade for fall 2014 (n=209) (78.89 ± 0.84% vs 75.80 ± 0.77%, p = 0.003, d = 0.26)(Fig. 3). The mean final grade for lower-achieving students in the fall 2015 class (n=60) was not significantly higher than the mean final grade for the lower-achieving students in fall 2014 (n=86) (69.41 ± 1.23% vs 66.71 ± 1.38%, p = 0.072).

Figure 3. Comparison of final grades for the full class and lower-achieving (<60% on individual exam 1) students. Error bars are standard error.

The mean final grade of male students in 2014 (n= 130) was not significantly different than the mean final grade of female students (n= 79) (76.94 ± 1.05% vs 76.38 ± 1.39%, p = 0.335) (Fig. 4). The mean final grade of STEM majors in 2014 (n= 114) was not significantly
different than the mean final grade of non-STEM majors (n= 86) (75.51 ± 1.11% vs 76.17 ± 1.32%, p = 0.704).

In fall 2015 the mean final grade of male students (n= 141) was significantly higher than the mean final grade of female students (n= 90) (80.55 ± 0.88% vs 76.30 ± 1.36%, p = 0.01, d = 0.37). The mean final grade of STEM majors in fall 2015 (n= 116) was significantly higher than the mean final grade of non-STEM majors (n= 108) (82.54 ± 0.98% vs. 74.88% ± 11.60%, p > 0.001, d = 0.69).

Figure 4. Final grades based on demographics for fall 2014 and fall 2015. Error bars are standard error.
Students in fall 2015 had significantly higher attendance than students in fall 2014 (85.33 ± 1.08% vs. 82.02 ± 1.66%, p = 0.05, d = 0.18). Fall 2015 attendance was positively correlated with final grades (Fig. 5).

In fall 2014 there were no significant differences in the breakdown of quizzes, homework, and exams except for quizzes between lower and upper-classmen (Table 1). There was a significant difference between the homework scores of non-STEM and STEM majors in fall 2015, along with significant differences between the exam scores for males and females and non-STEM and STEM majors (Table 1). Lower-achieving students in fall 2015 had significantly
higher scores on homework \((n=60)\) than lower-achieving students in fall 2014 \((n=86)\) \((94.15 \pm 2.60\% \text{ vs. } 80.33 \pm 2.59\%, \ p < 0.05, \ d = 0.68)\).

Table I. Student grades broken down by semester and demographic. Errors are standard error.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Major*</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>2014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quiz</td>
<td>69.91±2.87</td>
<td>69.38±1.97</td>
</tr>
<tr>
<td>Homework</td>
<td>87.99±1.86</td>
<td>84.26±1.87</td>
</tr>
<tr>
<td>Exam</td>
<td>75.21±1.41</td>
<td>74.92±0.97</td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quiz</td>
<td>83.50±2.01</td>
<td>86.53±1.21</td>
</tr>
<tr>
<td>Homework</td>
<td>96.07±1.94</td>
<td>98.59±1.38</td>
</tr>
<tr>
<td>Exam</td>
<td>70.39±1.32</td>
<td>77.58±0.86</td>
</tr>
</tbody>
</table>

*Undeclared majors not included
**Bolded groupings represent statistically significant differences within demographic, \(p\)-value<0.05.

Discussion

While neither semester showed progressive improvement in exam grades for each exam, there was improvement in fall 2014 from the first two exams to the final two exams. This indicates that there was a progressive improvement in the individual attempts of the two-stage
cooperative exams from the first half to the second half of the semester in fall 2014. There is not a progressive improvement in the fall 2015 individual attempts in the exams. Instead, the individual attempts for exam 1, exam 3, and the final are not different with exam 2 being significantly lower than the other exams.

To remove any complication from repeated material present in the two-stage cooperative exams and compare between semesters, progressive improvement was also analysed using normalized change scores with pre-scores as the individual attempt and post-scores as the group attempt for each exam (Marx and Cummings, 2007). This measurement is a proxy for Vygotsky’s (1962) zone of proximal development, the area between what a student can accomplish alone and what they know with the help of others.

Students in the fall 2015 class showed a decrease in the normalized change scores over the course of the semester. This indicates that their individual scores became closer to their group scores, shrinking the zone of proximal development. In contrast, students in the fall 2014 class had progressively larger normalized change scores for each exam, suggesting that the exam style alone is not sufficient to reduce the zone of proximal development. Zipp’s (2007) study used two-stage cooperative exams that were non-cumulative and found that students had increased short-term learning over the course of the semester. Our results show that this is not always the case, and pedagogy or repeated material also comes into play for student learning with two-stage cooperative exams.

Contrary to what was found in Ryan and Reid’s (2016) study, our student-centered lower-achieving students did not show significant improvement compared to the interactive lower-achieving students by the end of the semester. There may have been a smaller impact on lower-
achieving students between an interactive to student-centered class and a didactic to student-centered class used in Ryan and Reid’s (2016) study.

However, the lower-achieving students did have significantly higher homework grades in the student-centered class compared to the interactive class. This is promising because the homework in the student-centered class was given on MasteringGeology and graded for correctness, whereas the interactive class’s homework was graded for completion. With a larger number of assignments (33 vs 5) students in fall 2015 would spend more time on the material. There was a smaller percentage of students in this group in 2015, possibly suggesting that a student-centered approach or change in homework has an effect on reducing the size of this population, rather than helping them learn better. However, since we have no measure of the incoming knowledge of the students, we cannot attribute the change to the pedagogy.

Plate tectonics questions were covered in all four exams, giving students the greatest opportunity to learn from repeated exposure to the material in the two-stage cooperative exams. From the first exam to the final exam students in both semesters showed an increase in retention of plate tectonics content questions. The increases (13.20% and 11.14%, respectively) were not different, suggesting that the amount of learning of plate tectonics material at the end of the semester does not appear to be related to the pedagogy, and that the exam style may play a larger role in it.

Assuming both classes had the same knowledge and ability at the beginning of the course, the comparison of final course grades shows that there was a significant increase between fall 2014 and fall 2015. The significantly higher attendance in fall 2015 compared to fall 2014 is similar to other student-centered classes (Fig. 3,5) (e.g., Mazur, 1997; McConnell et al., 2006).
This increase in attendance because of the change in pedagogy is likely one of the largest factors for the significantly higher final grades in fall 2015 compared to fall 2014.

Male students performed statistically significantly better than female students in fall 2015, but did not in fall 2014. Contrary to what we would have expected from literature, this suggests that this implementation of student-centered pedagogy helped male students more than female ones (e.g., Gross et al., 2015). STEM majors had significantly higher final grades than non-STEM majors in fall 2015, though there was no statistical difference in fall 2014. This may be due to the presence of more male students in STEM majors.

To assess the increase in final grade, we broke down the student grades into quizzes, homework, and exams (Table 1). Students in the fall 2014 class for each demographic had the same grades in each category, except for lower-classmen having higher quiz grades than the upper-classmen. However, in fall 2015 male students had significantly higher exam scores compared to female students, and STEM majors had significantly higher exam and homework scores compared to non-STEM majors. The quiz scores were not a factor in the significant difference seen in the final grades of male and female students and the STEM and non-STEM majors.

Conclusions

While the results from this study cannot be generalized to a wider population, they offer insight into the possible gains from changing to a fully student-centered class. Many instructors find transferring to active learning intimidating (Stains et al., 2018), and it may be easier to start by changing from traditional to interactive classes. However, this study shows that there can be significant content retention gains for students in a fully student-centered class. This is shown by the higher final grades compared with the interactive class, likely due to higher attendance, change in homework, and the reduction of the zone of proximal development in two-stage
exams. This fully active pedagogy encourages and rewards students coming to class and having learning interactions with their peers. However, these gains are not evenly distributed among the demographics; male students and STEM majors showed the greatest improvement.

**Disclosure Statement**

No potential conflict of interest was reported by the authors.

**References**


CHAPTER 3. GENERAL CONCLUSION

Benefits of Student-Centered Pedagogy

The majority of studies on active learning techniques have compared learning gains with didactic courses, and shown them to be more effective (e.g., Freeman et al., 2014). It is necessary to compare different active learning pedagogies to each other for effectiveness. Comparing an interactive and student-centered course gives insight into how these two active pedagogies effect student learning.

In this large, introductory geology course the students in the interactive course had progressive improvement in their individual exam grades from the first half of the semester to the second half. This was not seen in the exam grades from the student-centered class. Instead, students in the student-centered class shrank the zone of proximal development (Vygotsky, 1962), as measured by calculating the normalized change scores from the individual and group attempts in each exam. Students from the interactive course increased the knowledge gap in the zone of proximal development over the course of the semester.

Students in the student-centered course had higher final grades compared to the interactive course. This increase is likely due to higher attendance, change in homework, and the reduction of the zone of proximal development in two-stage exams. However, not all students increased their scores evenly. The increase in final grades for the student-centered class was mainly driven by male students and STEM majors.

The student-centered pedagogy encourages and rewards students coming to class and having learning interactions with their peers. Even in large, introductory courses there are benefits to student learning when switching from an interactive to a fully student-centered
pedagogy. While there are fewer opportunities for one-on-one interactions with the instructor, students still increase their learning with increased peer instruction.

References
