STUDENT-CENTERED ACTIVE LEARNING ENVIRONMENT FOR UNDERGRADUATE PROGRAMS (SCALE-UP): EFFECTIVE TOOL FOR BIOLOGY?

A Thesis
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Melissa Rae Stotz

In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Program:
Education

May 2019

Fargo, North Dakota

North Dakota State University
Graduate School

Title

STUDENT-CENTERED ACTIVE LEARNING ENVIRONMENT FOR UNDERGRADUATE PROGRAMS (SCALE-UP): EFFECTIVE TOOL FOR BIOLOGY?

By

Melissa Rae Stotz

The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

SUPERVISORY COMMITTEE:

Erika Beseler Thompson
Chair

Chris Ray

Jennifer Momsen

Approved:

5/10/19
Date

Chris Ray
Department Chair

ABSTRACT

The Student-Centered Active Learning Environment for Undergraduate Programs (SCALE-UP) method incorporates active learning pedagogies into space designed to facilitate effective active learning. Methods predominately used to demonstrate the effectiveness of active learning in STEM fields do not generally account for differences in student characteristics; furthermore, there is a lack of data sources that measure student-centered educational practices. This study examined the impact of SCALE-UP on student achievement in introductory biology, as evidenced by course grades. A regression framework was used to account for student characteristics. Course syllabi, classroom observation data, and an instructor interview were examined to gain deeper understanding of teaching practices across classes being compared. Findings indicate the SCALE-UP classroom did not directly impact biology course grades; however, it did impact the nature of active learning techniques used during the course. Implications for practice and future research were discussed.

ACKNOWLEDGMENTS

I would like to thank Dr. Beseler Thompson for her extraordinary support and expert guidance through the progression of this thesis. Without her encouragement, believing in me more than I believed in myself at times, the process would have been much more difficult to maneuver. Further, I want to thank Dr. Ray for his doyen assistance in quantitative research, and Dr. Momsen for her expert guidance in active learning pedagogies in biology.

Although I am unable to address her by name, I feel it important to acknowledge my gratitude to the instructor who allowed me to follow her Biology course for my research; not only did she give me her time for the interview, she also provided the syllabi and student grade data for the five course sections that were studied. Additionally, thank you to Dr. Boyer who shared COPUS data for the five course sections.

Last, but certainly not least, a sincere thank you to my family and friends. Thank you for supporting me, graciously putting up with my whining, and not taking it personal when I frequently had to say “I can’t --- I have homework”.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. INTRODUCTION

"Learning is not a spectator sport. Students do not learn much just by sitting in classes listening to teachers, memorizing pre-packaged assignments, and spitting out answers" (Chickering & Gamson, 1987, p. 3). "Active learning engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work" (Freeman et al., 2014, pp 8413-8414). Active learning is grounded in the theory of constructivism which emphasizes the active engagement of the learner in the construction of new knowledge that is built upon existing knowledge (Dori & Belcher, 2005; Von Glaserfeld, 1989). Active learning is not new. However, it has experienced a surge of popularity in recent years, as higher education strives to prepare today's college students for the twenty-first-century workforce. For science, technology, engineering and mathematics (STEM) education, the National Research Council (2015), declared active learning methods are critical in shaping the nation's future. For biology education specifically, the American Association for the Advancement of Science (2011) explicitly recommends creating active learning environments in all undergraduate biology courses. Using active learning strategies in the college classroom are indisputably more effective for student learning compared with traditional pedagogies (Freeman et al., 2014; Prince, 2004). For active learning to occur, the responsibility of learning shifts from being teacher-centered to student-centered. In teacher-centered pedagogies, the students listen while the focus is on the teacher. Student-centered pedagogies occur when the focus is shared between the students and the teacher. Student-centered instruction encourages student group work, engagement, and collaboration. There are wide varieties of active learning techniques and settings that can be used. An active learning tool that has been gaining popularity has been the Student-Centered

Active Learning Environment for Undergraduate Programs (SCALE-UP) approach, which provides a specialized active learning environment (Beichner et al., 2007).

The SCALE-UP classroom environment offers an exciting opportunity for faculty who have an interest in delivering a highly interactive, collaborative, hands-on learning experience to their large-enrollment courses. Social constructivism, according to Vygotskiĭ (1962), posits all knowledge is constructed by the learner and comes from social interactions. Carefully designed to stimulate the social constructivist teaching method, the SCALE-UP classroom is technology-rich and its physical layout, coupled with student-centered pedagogies, have been shown to be effective in improving student learning (Beichner et al., 2007; Brooks, 2011; Brooks & Solheim, 2014; Dori & Belcher, 2005; Felege & Ralph, 2018; Hao, Barnes, Wright, & Kim, 2018; Rogers, Keller, Crouse, & Price, 2015). Developed in 1997 by Robert Beichner, professor of Physics at North Carolina State University, the goal of the SCALE-UP project was to reform introductory physics learning (Foote, Neumeyer, Henderson, Dancy, & Beichner, 2014). Soon the SCALE-UP environment spread to the STEM fields; today it is recognized as a highly effective classroom environment being used by disciplines of all areas.

The student-centered classroom layout, furniture, and technologies create a unique learning environment that was designed to facilitate social constructivism methods, such as collaboration, group work, peer-to-peer discussions, and student-to-instructor discussions. The moment a person steps into a SCALE-UP classroom, they know they are not in an ordinary classroom. Described by Beichner et al. (2007), a SCALE-UP classroom has no front of the room. The instructor podium is located at the center of the room to encourage student-centered pedagogies; the instructor functions as a facilitator of learning rather than transmitting knowledge. Student seating is at large round tables that seat nine students; student table shape and sizing was intentionally designed to be conducive to group work and inter-group interaction. Student work can be done individually, in three groups of three, or a larger group of nine. Rolling chairs with no arms were selected for student seating, so that they can move around and sit close together to collaborate. Each student table provides tools that support collaboration and group work, such as whiteboard space, an electronic display, three digital connections to the electronic display (one for each group of three students), and three microphones. The instructor can project any one of the student table electronic displays to the entire class to provide a whole-class cooperative learning experience. Since there is no front of the room, there are multiple instructor displays located around the room so that all students have a sight line to the content. Student tables need to be positioned so that instructors can freely move between them; this is an important element to the design, allowing the instructor easy access to help guide learning. Equally important as the classroom's physical elements, implementing effective active learning pedagogies in the SCALE-UP space must be achieved to maximize the benefits of the SCALE-UP method.

Statement of the Problem

One notable shortcoming of the preponderance of active learning studies that measure student learning gains is that their validity has been questioned for not controlling for student characteristics across groups. Theobald and Freeman (2014) demonstrated that different results could occur when analyzing the same data, with and without controlling for nonequivalence – meaning the frequency of student characteristics that may impact student performance were unequal across groups being studied.

Furthermore, the literature is clear that outcomes are maximized by the use of effective active learning pedagogies in the SCALE-UP classroom (Beichner et al., 2007; Brooks &

Solheim, 2014; Dori & Belcher, 2005; Gierdowski, 2012; Hunley & Schaller, 2009; Smith, Jones, Gilbert & Wieman, 2013). One of the challenges of researching the impact of active learning techniques and the SCALE-UP method is that there are no guidelines for measuring effective teaching practices (Stains et al., 2018). According to Beichner et al. (2007), before teaching with the new SCALE-UP approach, instructors need time to learn how to implement the new strategy effectively and overhaul the course. Until they gain experience, even instructors who properly prepare themselves, and their course, may feel unfamiliar and uncomfortable delivering their course in such a student-centered manner. The identified weakness of the majority of active learning research lacking control of student nonequivalence, coupled with the lack of studies that effectively account for the implementation of active learning pedagogies over time, provide the basis for a study in this area.

Purpose of the Study

The purpose of this study is to examine the impact of a SCALE-UP learning environment on student achievement in Biology 151, General Biology II, as evidenced by student course grades, while accounting for instructor pedagogy. The following research questions guided this study:

1. To what extent does the use of a SCALE-UP classroom impact student grades in Biology 151, General Biology II?
2. How do active learning pedagogies differ between the SCALE-UP classroom and a fixed-seat auditorium?

Significance of the Study

The SCALE-UP initiative is costly regarding space, technology, and time. When deciding whether to embark on this journey, university administrators and faculty will benefit from the findings of this study. The results will help administrators make budgetary decisions whether to fund the high cost of a SCALE-UP classroom, and help inform faculty when deciding whether it is worth the considerable time investment to learn how to use student-centered teaching methods and restructure their course. By necessity, this mixed methods approach accounts for student characteristics across the groups being studied, as well as provides an in-depth picture of active learning pedagogies used in the SCALE-UP classroom. Using these methods to identify the impact of a SCALE-UP classroom on student outcomes contributes to the current literature.

Organization of the Study

The next chapter includes a comprehensive review of active learning and SCALE-UP literature and research. Chapter 3 describes the research design, methods, population, data collection, and analysis. Chapter 4 includes an analysis of the collected data and a summary of findings. Lastly, Chapter 5 presents a discussion of the implications of the findings of the study, limitations of the study, along with recommendations for future research.

CHAPTER 2. LITERATURE REVIEW

Dewey (1897), a renowned philosopher and educational reformer, believed that learning should be student-centered rather than teacher-centered and takes place through experiences and interactions with the curriculum; which is the basis for active learning. This chapter reviews the literature relating to active learning in general, its theoretical basis, as well as how it relates to science, technology, engineering, and mathematics (STEM) education and biology. The Student-Centered Active Learning Environment for Undergraduate Programs (SCALE-UP) teaching method was designed to facilitate active learning and will be the next area of focus in this chapter. A review of the SCALE-UP literature found several studies that aimed to identify the key elements to improved student learning gains: active learning pedagogies, the classroom space design, or a mixture.

Active Learning

One of the challenges in researching active learning is that there is no one definition. Freeman et al. (2014), collected 338 definitions from people attending active learning seminars and found consensus for the following definition, "Active learning engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work" (pp 8413-8414).

Constructivism and Social Constructivism are learning theories that underlie the principles of active learning. Constructivism emphasizes the active engagement of the learner in the construction of new knowledge that is built upon existing knowledge (Dori & Belcher, 2005; Von Glaserfeld, 1989). The foundations of Constructivism come from the works of Dewey, Bruner, Vygotsky, and Piaget (Bada, & Olusegun, 2015). According to Bada and Olusegun

(2015), “To date, a focus on student-centered learning may well be the most important contribution of constructivism” (p. 70). Constructivism theory asserts knowledge cannot be passively learned; students need to actively construct knowledge in their own minds. According to Vygotskiĭ and Cole (1978), social constructivism emphasizes that learning is constructed in a social context as individuals find meaning that is applicable to their experiences. The tenets of social constructivism is that learning is active and social.

Dewey (1915) wrote:

> The Teacher and the book are no longer the only instructors; the hands, the eyes, the ears, become respectively the starter and the tester. No book or map is a substitute for personal experience; they cannot take the place of the actual journey. (p. 74)

Dewey’s philosophy of the importance of experiential learning has become increasingly popular in higher education over the past three decades. In “Seven Principles for Good Practice in Undergraduate Education,” Chickering and Gamson (1987) include active learning techniques as one of the principles. The seven principles are based on 50 years of research on effective teaching and learning practices.

Further illustration of this modern resurgence for active learning comes from the Association of American Colleges and Universities in a published report in 2007, *College Learning for the New Global Century*, authored by the Liberal Education and America’s Promise (LEAP) council. In the report, LEAP (2007) directed policy leaders to significantly increase their investments in active learning teaching strategies to provide all students with valuable opportunities to attain the anticipated learning outcomes, stating “The use of effective and engaging educational practices will be the key to higher achievement for contemporary college students” (p. 11).

Effectiveness of Active Learning

Research has strongly suggested that active learning leads to increased student outcomes (Freeman et al., 2014; Haak, HilleRisLambers, Pitre, & Freeman, 2011; Hake, 1998; Knight & Wood, 2005; McCarthy & Anderson, 2000). In a comprehensive meta-analysis of 225 studies that compared active learning to traditional lecturing, the calculated risk ratio suggested students taught with active learning techniques experienced a 12% reduction in course failure rates (Freeman et al., 2014). These outcomes have been persistent across disciplines, including humanities and social sciences (McCarthy & Anderson, 2000), physics (Hake, 1998), and other STEM courses (Freeman et al., 2014).

Hake (1998) and McCarthy and Anderson (2000) found evidence that active learning enhances problem-solving skills, promotes deeper conceptual understanding, and encourages student-centered, interactive engagement and participation. Interactive engagement between students and the instructor, to solve problems, has been shown to improve student learning. In contrast, passive learning occurs when "…students passively absorb pre-processed information and then regurgitate it in response to periodic multiple-choice exams" (McCarthy & Anderson, 2000, p. 279). Generally speaking, the literature reviewed in this paragraph poses passive learning as surface learning, and active learning as being engrained and fully understood.

Active Learning in STEM Education

Strong advocacy for active learning in the STEM fields has been called for by the President's Council of Advisors of Science and Technology (2012):

> Given the size of the body of peer-reviewed research about active learning; the variation in experimental design among the studies; the diverse settings and subjects used; the consistency of findings across many STEM disciplines; and the concordance between

> studies of subjects under experimental conditions and studies of real STEM classes, the conclusion is convincing: teaching methods that require active engagement of the mind lead to more learning than does lecturing alone. (p. 84)

The importance of reforming STEM education practices to include active learning techniques has been demonstrated by several national reports such as the American Association for the Advancement of Science, 2011; the National Research Council (NRC), 2015; and the President's Council of Advisors of Science and Technology, 2012. Discipline-Based Education Research (DBER), funded by the National Science Foundation, investigated the effective teaching and learning methods that explain learning in the STEM fields (NRC, 2015). According to the NRC (2015), DBER scholarship strongly supports student-centered instructional strategies, as a solution to increase learning gains.

Evidence supporting the benefits of active learning was found when Hake (1998) compared pre/posttest concept inventory data and problem-solving test scores for 6,542 high school, college, and university students taking introductory physics courses in a classroom that used active learning methods versus a traditional lecture-based approach. A consistent analysis was obtained by using the average normalized gain on concept inventory tests. Hake defined the average normalized gain as "…the ratio of the actual average gain (%<post> - %<pre>) to the maximum possible average gain (100 - %<pre>)" (p. 1). The analysis suggests that the classes that used interactive-engagement in the classroom experienced a gain of almost two standard deviations above that of the traditional courses, and improved students' problem-solving ability; concluding the use of interactive engagement strategies increase the effectiveness of introductory physics courses compared to that obtained with traditional methods.

Numerous studies suggest that active learning techniques are effective in improving student learning in the STEM fields. In their comprehensive meta-analysis of 225 studies of undergraduate STEM students, Freeman et al. (2014) suggested active learning should be supported as the "…preferred, empirically validated, teaching method" (p. 8410). For the meta-analysis, Freeman et al. (2014) followed best practice guidelines in quantitative reviews and found that active learning increases concept inventory exam scores by just under a half standard deviation and students in lecture courses are 1.5 times more likely to fail than students in an active learning classroom. Additionally, Freeman et al. (2014) stated:

> The heterogeneity analyses indicate that *(i)* these increases in achievement hold across all of the STEM disciplines and occur in all class sizes, course types, and course levels; and *(ii)* active learning is particularly beneficial in small classes and at increasing performance on concept inventories. (p. 8412)

Based on the impact found in their study, Freeman et al. (2014) concluded that traditional lecturing should no longer be used as a control group in future experiments, implying it would be unethical. To illustrate, if none of the students in the 225 studies were in a traditional lecturing control group, there would have been 3,516 fewer students who failed. Translating, conservatively, to over $3,500,000 in tuition that would have been saved by the study population.

Active Learning in Biology Education

The National Research Council (2003) called national attention to the need to reform undergraduate biology teaching and learning. In further support, the American Association for the Advancement of Science (2011) explicitly recommended creating active learning environments in all undergraduate biology courses. These calls for reform were grounded in research on the effectiveness of active learning techniques used in biology courses. Biology, being a STEM field, is included in the preceding review of active learning in STEM education. As with studies of STEM fields, overall, studies that examine active learning in biology, specifically, have found that students performed better than in sections taught in a traditional lecture format (Connell, Donovan, & Chambers, 2016; Freeman et al., 2007; Haak et al., 2011; Knight & Wood, 2005; Udovic, Morris, Dickman, Postlethwait, & Wetherwax, 2002).

Supporting the benefits of active learning in biology, Haak et al. (2011), used a regression model in a study of 3,338 students and found that increasing structure and active learning in an introductory biology course improved the performance of all students, and reduced the achievement gap of disadvantaged students. Disadvantaged students were defined as those who are part of the Educational Opportunity Program (EOP) at the University of Washington. The EOP includes students from "…educationally or economically disadvantaged backgrounds; most are first in their family to attend college" (Haak et al., 2011, p. 1214). The majority of underrepresented minority students (76.5%) at the University of Washington were also in the EOP; therefore, disadvantaged students from all backgrounds are represented in the analysis. The introductory biology course was studied because the achievement gap in that course was amongst the highest at the University of Washington. Low, moderate, and high use of structured active learning techniques were studied for effectiveness. The components of a highly structured course, defined by Haak et al. (2011) required students to "...(i) prepare for class sessions, (ii) use clickers or random-call responses to participate in class sessions that were focused entirely on active-learning exercises, and (iii) complete a weekly low-risk assessment in the form of a practice exam" (p. 1214). The study used a generalized linear mixed model to determine that the highest predictors of the course grade came from active learning, predicted grade (calculated using college GPA and SAT-verbal score), and EOP status. The findings suggest the highly structured course significantly improved all students' learning outcomes, although to a greater extent for EOP students. The results were verified with further analysis that compared EOP versus non-EOP student performance; the highly structured course reduced the EOP achievement gap from .80 to .44 grade points. The use of a highly structured course that uses active learning methods was found to be effective in improving student learning outcomes for all students while reducing the achievement gap for EOP students. A similar study conducted by Freeman et al. (2007) found "introductory biology students benefit from highly structured active-learning environments and that highly structured course designs may have a particular benefit for students who are at high risk of failing the course" (p. 137).

Citing the evidence from Freeman et al. (2014), that active learning produces learning gains and significantly lower failure rates, Connell et al. (2016) tested whether there was a difference in student learning outcomes if students participated in a biology course that used student-centered methods extensively compared to moderate use of student-centered methods. The same instructor taught two sections of the same large-enrollment introductory biology course, during the same quarter, and covered the same material; the only difference between the sections was the amount of student-centered activities that were used. The section that used more student-centered methods was referred to as the Extensive section, and the section that used a moderate amount of student-centered methods was referred to as the Moderate section. The student demographics between the two sections were similar; variables tested for significance included class standing, gender, number of years in high school biology, and the number of science courses taken in college.

To assess what the instructor and students were doing in these courses, Connell et al. (2016) observed the classes using the Classroom Observation Protocol for Undergraduate STEM

(COPUS). The COPUS tool is defined and explained in more detail later in this chapter. Students in the Extensive section were observed doing much more group work than the Moderate section. The Moderate section students spent more time listening to the instructor than the students in the Extensive section. Both sections spent much time answering questions asked by the instructor, and asking questions of their own. Meanwhile, the instructor of the Moderate section was observed lecturing twice as often as in the Extensive section. In the Extensive section, the instructor was observed managing group work and working one-on-one with students; which did not occur in the Moderate section. Content knowledge was assessed by giving both sections the same three multiple-choice exams, as well as a comprehensive pre and post content assessment.

Analyzing the data, Connell et al. (2016) found that the students in both sections performed equally on the content pre-assessment. A multiple regression model was used to determine whether a student's post-assessment score was affected by the class section in which the student was enrolled. Students who participated in the Extensive section scored about 2.5 points higher than students in the Moderate section with all other factors held equal. Findings suggest that the extensive use of active learning methods resulted in a higher degree of student learning gains compared to the moderate use of active learning methods.

SCALE-UP

In order to facilitate the integration of active learning methods into physics classes Robert Beichner developed a teaching methodology known as Student-Centered Active Learning Environment for Undergraduate Programs (SCALE-UP) at North Carolina State University (Foote et al., 2014). A SCALE-UP classroom is defined by Beichner et al. (2007) as a "…highly collaborative, hands-on, computer-rich, interactive learning environment for large, introductory college courses" (p. 1). Described another way, "…a place where student teams are given interesting things to investigate while their instructor roams -- asking questions, sending one team to help another, or asking why someone else got a different answer" (Beichner, 2008). Beichner et al. (2007) referred to SCALE-UP as a project that includes a specifically designed classroom environment, pedagogy that supports active learning, and prepared teaching materials. The original SCALE-UP project combined the course instruction and laboratory work so that all activities occur in the same classroom with the same students and the same instructors. With this arrangement, the classroom activity and laboratory experiment can be completed in a seamless sequence, producing a positive impact on learning.

Beichner et al. (2007) emphasized great effort went into the careful designing of the original SCALE-UP classroom since the space needs to support lecture, student group work, and laboratory experiments. The final iteration of the design process resulted in student seating at 7' round tables that seat nine students. The sizing is intentional to allow for three groups of three students for group work. Activities may bring the three groups together to collaborate as a group of nine students, while other activities may start as one group of nine students. The placement of the student tables needs to allow for easy instructor movement between tables. Each student table has access to classic whiteboards and an electronic display for student table collaboration. There are multiple ceiling-mounted projectors to display what is being projected so that students, no matter where they are sitting, can see what is being displayed. In the original project, each student table was equipped with lab equipment for conducting experiments and three laptops, one for each student group of three, to allow for group cohesion while collaborating on group activities. Some instructors argue that having a laptop for each student would be best to allow for individual assignments, quizzes, and tests. Laptops are recommended over desktop computers because they take less space on the table, and the instructor can ask students to close the lids when their attention should not be on the computer (Beichner, et al., 2007). During engaging activities, the instructor is walking around the classroom observing and guiding the activities; therefore, the instructor needs a wireless microphone so everyone will hear when necessary. Typically, the instructor station is permanently installed near the center of the classroom (Beichner & Saul, 2003). “Each table of students seems to become its own little society and develops a unique personality” (Beichner et al., 2007, p. 26).

History

SCALE-UP was developed for a large enrollment physics course at NSCU in 1997 (Foote et al., 2014). Beichner et al. (2007) described the project foundation was a result of the Integrated Math, Physics, Engineering, and Chemistry (IMPEC) project at NCSU. The IMPEC project, which used extensive active learning methods, was successful for student learning but was suspended because it could only accommodate up to 36 students per year. The SCALE-UP project was started to take what was learned from the IMPEC project and scale it up for classes up to 100 students.

Additional applications of the SCALE-UP project have resulted in name changes. The original expansion stood for Student-Centered Activities for Large Enrollment Undergraduate Physics (Beichner, Bernold, Burniston, & Dail, 1999). Secondary implementations are using the SCALE-UP method for other disciplines, so the expansion was changed to Student-Centered Activities for Large Enrollment Undergraduate Programs (Beichner et al., 2007; Rogers et al., 2015). Another popular expansion found in the literature is Student-Centered Active Learning Environment with Upside-down Pedagogies (Foote et al., 2014). Regardless of the expansion words, each one models the original project.

Since the inception of the SCALE-UP project, the method has spread worldwide; sometimes the original method is followed precisely, but more often it is modified to suit specific needs (Beichner et al., 2007, Foote et al., 2014). According to Foote et al. (2014), since the first SCALE-UP classroom was built in 1997, there are at least 314 departments in 189 colleges and universities in 21 countries using the SCALE-UP approach. Of the 314 departments using SCALE-UP, 37% are Physics, 12% are Chemistry, 14.6% are Biology with health professions, 7.5% are Engineering, 7.1% are Mathematics and Statistics, 2.6% are Other STEM, and 19.2% are Non-STEM.

Secondary Adaptations

Secondary implementations frequently modify the original SCALE-UP project to meet institutional needs and constraints (Foote et al., 2014, Knaub, Foote, Henderson, Dancy, & Beichner, 2016). Beichner (2014) stresses the primary consideration when implementing a SCALE-UP classroom is to maximize student collaboration. A review of the literature has found that a prominent modification has subverted the original intention to combine the laboratory work in the SCALE-UP classroom, keeping the laboratory separate (Cotner, Loper, Walker & Brooks, 2013, Felege & Ralph, 2018, Foote et al., 2014, Sonreal & Wyse, 2017, Stoltzfus & Libarkin, 2016).

Foote et al., (2014), in a review of secondary SCALE-UP sites, found rooms that were built specifically for physics departments most frequently included lab equipment, following the original project. Rarely does any other department include specialized lab equipment in their implementations. Additionally, only about 50% of secondary implementations included laptops or computers at the student tables (Foote et al., 2014, Knaub et al., 2016). Rather than provide the student laptops or computers, to cut down on costs, many institutions opt to provide each student table with thee ports for students to connect their own laptops/devices (Brooks, 2011, Cotner, et al., 2013, Felege & Ralph, 2018, Sonreal & Wyse, 2017).

To further reduce the costs of a SCALE-UP classroom, several secondary implementation sites have questioned the value of the student table technology, such as the three laptops (or connections for personal laptops) along with the electronic display monitor (Knaub et al., 2016, Sonreal & Wyse, 2017, Stoltzfus & Libarkin, 2016). Sonreal & Wyse (2017) completed a study and found that student achievement was the same whether they were in a high technology SCALE-UP classroom or in a low technology SCALE-UP classroom; both the high and low technology classrooms had round tables to facilitate student collaboration.

Challenges of SCALE-UP Implementation

Beichner et al. (2007) offer, as challenges to the implementation of SCALE-UP: faculty and department acceptance of the new teaching approach, time constraints, and lack of funding. The technology-rich environment costs are substantially more than a traditional classroom, which often impedes the implementation of a SCALE-UP classroom. Also, instructors may be reluctant to teach SCALE-UP for the first time because the new method is unfamiliar and uncomfortable. Adding to these challenges, first-time SCALE-UP instructors need to invest a great deal of time to prepare for this type of student-centered approach; the method requires an overhaul of the course, as well as time for faculty to learn how to implement the new strategy effectively. Persistence to find the right learning strategies that work with the curriculum is often necessary before improved student learning outcomes will be found.

Effectiveness of SCALE-UP

The SCALE-UP learning environment provides a classroom design that promotes the use of active learning techniques for large enrollment introductory courses (Beichner et al., 2007).

Not surprisingly then, the improvements to student learning associated with the use of SCALE-UP closely mirror the improvements associated with active learning.

The largest study of the impact of being taught in a SCALE-UP classroom was collected by the SCALE-UP project (Beichner et al., 2007). Data, including demographic characteristics, was collected between 1997-2002 that compared the attitudes and academic results of nearly 16,000 traditional and SCALE-UP students. “Besides hundreds of hours of classroom video and audio recordings, we have conducted numerous interviews and focus groups, carried out many conceptual learning assessments (using nationally recognized instruments in a pretest/posttest protocol), and collected portfolios of student work” (Beichner et al., 2007, p. 34).

As described by Beichner (2008), Beichner et al. (2003), and Beichner et al. (2007), the SCALE-UP classes showed increased conceptual understanding compared to the traditional lecture-based classes, as evidenced by evaluating normalized gains on pretest/posttest conceptual learning assessments. Further, the top third of the students in the SCALE-UP classes showed the greatest improvement in conceptual understanding, suggesting this may be the result of the top third of students teaching their peers. The study also concluded that performance in the second-semester physics class had improved following participation in the first-semester SCALE-UP physics class, whether the second-semester course was taught in a lecture-based class or SCALE-UP. Furthermore, the failure of at-risk students (defined as students whose SAT math scores < 500) in a later Engineering Statics course was cut in half. The ratio of failure rates (receiving a grade lower than C-) was found by dividing the percentage of students failing in the lecture-based sections divided by the percentage of students failing in the SCALE-UP sections. Failure rates were typically reduced by 50%; especially for women and minorities whose failure rates were reduced by a factor of four or five. Comparing the results of randomly selected questions from an exam, the study found that the students who were in the SCALE-UP classroom could solve problems as well, or better, than the students who took the course in a traditional lecture-based classroom. Additionally, student interviews found that the attitudes of students who participated in the SCALE-UP class were improved. Attendance rates for students in traditional classes compared to SCALE-UP classes, having the same instructor, and the same attendance policy found class attendance was higher, typically over 90%, in the SCALE-UP class section.

These findings have been corroborated by other institutions who adopted the SCALE-UP method. Studies suggest improved learning gains and decreased failure rates for students who participate in a course in the SCALE-UP classroom compared to a lecture-based classroom (Brooks, 2011; Brooks & Solheim, 2014; Dori & Belcher, 2005; Felege & Ralph, 2018; Hao et al., 2018; Rogers et al., 2015). The SCALE-UP classroom environment encourages a student-centered, collaborative classroom (Beichner et al., 2007; Dori & Belcher, 2005). Dori and Belcher (2005) reported on the significance of the collaboration they observed in the SCALE-UP environment. The collaboration produced the building and sharing of knowledge with peers. Social constructivism was experienced through small and large discussion groups, and individual and group activities.

Limitations of the Studies

A limitation of many studies of active learning gains in STEM education is the lack of accounting for the differences in student characteristics across the classes being compared (Theobald & Freeman, 2014). In their research, Theobald and Freeman (2014) demonstrated a more effective way to analyze learning gains when an intervention has been applied without randomization. The methods used predominantly in the STEM education literature include raw change scores (Udovic et al., 2002), normalized gain scores (Beichner, 2008; Hake, 1998), normalized change scores (Marx & Cummings, 2007), and effect sizes (Andrews, Leonard, Colgrove, & Kalinowski, 2011); these were shown to be problematic because they did not control for nonequivalence – meaning the frequency of student characteristics that may impact student performance were unequal across groups being studied. Examples of characteristics include high school GPA, ACT composite score, gender, class standing, previous biology grade, pre-test exam score, EOP status, and minority status (Connell et al., 2016; Haak et al., 2011; Theobald & Freeman, 2014). Without controlling for student characteristics that lead to nonequivalence, there is no way to know whether differences between the treatment group and the control group are due to the intervention that was applied, or due to student nonequivalence. Theobald and Freeman (2014) suggest using a framework that will control for student nonequivalence; one example is to use linear regression. The first step towards controlling student nonequivalence is to collect data for all variables that could have an impact on learning gains. Once the variable data has been collected, regression can be used to learn which variables are most predictive of the outcome variable. "Linear regression provides both an estimate of this treatment effect and a test of whether the treatment effect really is significantly different from zero, *controlling for the influence of each of the other variables in the model"* [emphasis in original] (Theobald & Freeman, 2014, p. 46). Theobald and Freeman (2014) concluded: "…that linear regression should be a component of any analysis of nonrandomized instructional intervention" (p. 47). Notably, this is an analytical approach that has not been used in the majority of studies regarding the measurement of learning gains from the implementation of active learning techniques in SCALE-UP settings.

Furthermore, ample evidence suggests that active learning leads to learning gains in STEM undergraduate education; however, there is a lack of guidelines for measuring effective active learning pedagogies (Stains et al., 2018). Stains et al. (2018) argues that the majority of information relating to instructional practices is gathered through self-report surveys, which can compromise reliability, and are seldom applied nationally to provide reliable and valid data. The National Academies of Sciences, Engineering, and Medicine (2018) recognizes this limitation as evidenced by the following conclusion: “No data sources are currently available for most of the indicators of engaging students in evidence-based educational practices” (p. 10), and calls for an improvement in data collection. Studies need to account for both the accurate evidence of active learning pedagogies used, as well as how those pedagogies shift over time.

Classroom Space Design and Pedagogy

In addition to the classroom design, the efficacy of the SCALE-UP classroom hinges on the transformation of pedagogy (Beichner et al., 2007). Hunley and Schaller (2009) have argued "Institutions that assess the use of learning spaces on their campuses must also ascertain pedagogical practices that yield optimal learning; space and pedagogy are undeniably intertwined" (p. 34). A research design that studies student outcomes by only looking at the space is flawed because it does not take into account many other factors that may impact users, such as pedagogy, student attitudes, social interactions between the students, and classroom technology (Gierdowski, 2012).

Supporting the value for assessing teaching practices when evaluating the impact of active learning methods, Andrews et al. (2011) completed a study of the use of active learning techniques used in a biology course and notably found that active learning did not produce learning gains. The authors contend that active learning may have the potential to improve student learning substantially, but only if the instructor has the proper skills and knowledge to use it effectively. Science instructors, as opposed to education researchers, may not incorporate the necessary constructivist elements into their active learning techniques.

Teaching practices are impacted by the characteristics of the classroom, as well as the instructor (Cotner et al., 2013; Knaub et al., 2016). Beichner et al. (2007) stated that physical spaces could either encourage or discourage active learning methods. The SCALE-UP classroom is designed to maximize opportunities for student engagement with peers as well as the instructor. Pedagogy is an important component to the success of the SCALE-UP method (Beichner et al., 2007; Cotner et al., 2013; Hunley & Schaller, 2009; Knaub et al., 2016; Michael, 2006). At the beginning of a seven-year longitudinal study to measure student learning gains from being taught in a SCALE-UP classroom, without changing pedagogy, the expectations for improvement were not found (Rogers et al., 2015). After a series of adjustments to pedagogy throughout seven years, improved student outcomes were found.

The University of Minnesota conducted three studies relating to the effectiveness of their Active Learning Classroom (ALC), which was modeled after the SCALE-UP design. Brooks (2011) studied the relationship between the classroom space and student learning outcomes, keeping the pedagogy constant; Cotner et al. (2013) replicated this study. A follow-up study by Brooks and Solheim (2014) explored the impact of adapting pedagogy to the ALC space and the impact it had on student learning outcomes.

Brooks (2011) focused the attention of his study on the impact of a formal learning space, without changing pedagogy. The quasi-experimental design studied two sections of a biology course. One section was taught in a traditional classroom, while the other section was taught in the ALC. The study kept constant the time slot the sections were offered, the instructor, course, materials, assignments, and exams — the instructor "…made considerable effort to keep his approach to delivering course material the same in each section" (p. 722). The learning space was the only factor allowed to vary across sections systematically. The composite ACT score was the only student characteristic that was found to be significantly different between the sections. The ACT composite scores in the traditional classroom were significantly higher than the ACT composite scores in the ALC; therefore, the study expected the students in the traditional classroom to have statistically higher grades than the students in the ALC. However, there was no significant difference between the average final grades the students in the traditional classroom earned compared to the average final grades the students in the ALC earned. The ALC students earned higher grades than expected and outperformed the students in the traditional classroom. Next Brooks (2011) used a linear regression model to evaluate the relationship of the ACT composite scores as a predictor for course grades in each section and found them to be highly significant predictors for course grades. The conclusion of this study suggests that learning spaces can independently and significantly affect student learning outcomes; however, it is critical to note that other important factors, including college and high school GPA, were *not* controlled for in Brooks' study.

The Brooks (2011) study was replicated; again, controlling for the instructor, course material, and designed activities (Cotner et al., 2013). As with the original study, every attempt was made to hold the pedagogy constant, and compare the student outcomes being taught in a lecture-based classroom versus an ALC. Also similar to the original study, ACT was the only demographic that was found to be significantly different; the traditional classroom had, on average, higher ACT composite scores. Using a point estimate regression model, the study expected the ALC students to earn fewer points than were found; the ALC students earned half of a letter grade higher than expected. Using the same methodology as Brooks (2011), this study also found that the ACT composite scores in each class section to be a good predictor of course grades. Adding to the evidence found in the original study, the ALC students outperformed the students taught in the traditional classroom. One important observation was made: during the analysis of classroom behaviors, even though the instructor explicitly tried to hold his pedagogy constant between the two courses, through classroom observation, instructor behavior was slightly different; lecturing more in the traditional classroom, and holding more discussions and group activities in the ALC classroom.

The third study conducted at the University of Minnesota, described by Brooks and Solheim (2014), examined the impact of pedagogy transformation coupled with teaching in the ALC. In the investigation, two sections of the same course, taught by the same instructor, in the same ALC, one year apart were analyzed. After the first year of teaching the course in an ALC and not changing teaching practices, the instructor modified pedagogy to match the active learning space. In this study, the room was held constant, while teaching practices were modified. Although randomization could not be used, the student demographics were found to be no different in the two sections being studied. Comparing the course grades between the two sections strongly suggest that transforming teaching practices to include more active learning methods, making use of the ALC, had a significantly positive impact on student learning. Combining the findings of this study with the previous study, the following policy recommendations were suggested:

> (1) The construction of ALCs on college and university campuses are a worthwhile investment; (2) instructors teaching in these spaces should change their pedagogical approach when teaching in formal classrooms like the ALC; and (3) faculty development programs designed to support course redesign, pedagogical transformation, or

technologically enhanced learning deserve either continued or increased institutional support. (p. 60)

Similar to Brooks (2011) and Cotner et al. (2013), Stoltzfus and Libarkin (2016) compared student outcomes for those being taught in a traditional classroom to a SCALE-UP classroom. All three studied an introductory biology course for non-science majors, used learner-centered pedagogy, used similar research questions, and experimental design; however, the results were different. All three studies attempted to hold pedagogy constant in both classroom types being studied. As described above, Brooks (2011) and Cotner et al. (2013) both found that the physical space independently had a positive impact on student performance, while Stoltzfus and Libarkin (2016) did not. Stoltzfus and Libarkin (2016) used linear regression to evaluate the significance of variables on post knowledge scores and found gender, class level, and group effort were insignificant predictors of post knowledge. Next, stepwise regression was used for the variables identified to be significant, including pre-knowledge, individual effort, and section. Pre-knowledge and individual effort together were found to be significant variables, explaining 12.4% of the variance in post knowledge. Classroom type did not explain a significant portion of the variance, meaning it was not important in explaining post knowledge. Worth noting, Brooks (2011) and Cotner et al. (2013) analyzed course grades as the outcome variable, while Stoltzfus and Libarkin (2016) analyzed validated content knowledge as the outcome variable, and argued it is a better source for measurement of student learning.

Classroom observations have been found to be a prevalent method used to inform the researcher of the degree to which the pedagogy was transformed to utilize the active learning space, both by quantity and quality (Bailey, 2018; Connell et al., 2016; Dori & Belcher, 2005; Stains et al., 2018; Wolfe, 2008). Beichner (2008) reported North Carolina State University hired an external evaluator to observe and compare the traditional lecture-based and SCALE-UP classes, finding that the students in the SCALE-UP class asked questions that were more substantive and of higher cognitive levels, compared to the student questions in the lecture-based course. The observer made the following statement regarding the lecture class, “While this instructor attempted to make the large lecture section more interactive, the students did not exhibit behavior that signaled positive intellectual regard for the activity” (Beichner, 2008, p. 9). Dori and Belcher (2005) conducted several observations to analyze the students’ social outcomes from participating in their version of a SCALE-UP classroom; their findings conclude “…it was apparent that the social aspect was an important factor in the construction of knowledge and contributed to establishing new insights and sharing knowledge with peers” (p. 267).

Classroom Observation Protocol for Undergraduate STEM

Smith, Jones, Gilbert, and Wieman (2013) developed the Classroom Observation Protocol for Undergraduate STEM (COPUS). With the large body of evidence-based research that recommends using active learning techniques in the classroom, this observation tool allows a method for collecting information about the frequency with which particular instructor and student actions took place in the classroom. The COPUS tool:

> Documents classroom behaviors in 2-min intervals throughout the duration of the class session, does not require observers to make judgments of teaching quality, and produces clear graphical results…and can be used reliably by university faculty with only 1.5 hours of training. (Smith et al., 2013, p. 619)

Figure 1 illustrates a portion of the coding sheet for the COPUS tool. “Observers place a single checkmark in the box if a behavior occurs during a 2-min segment. Multiple codes can be marked in the same 2-min block” (Smith et al., 2013, p. 622). Figure 2 identifies the behavior codes used for COPUS. According to Smith et al. (2013), the validity of the COPUS tool was achieved by receiving feedback from experts in STEM teaching and classroom observations. Reliability of COPUS was found by analyzing inter-rater reliability; the observers came from diverse backgrounds and participated in two hours or less of training. Stains et al. (2018) found that instructors frequently change their teaching practices, and suggest "…at least four observations are necessary for reliable characterization of teaching" (p. 1469). One shortcoming of the COPUS tool is that it captures the quantity of instructor and student behaviors, but does not measure the quality of the behaviors (Stains et al., 2018).

	1. Students doing													2. Instructor doing												Comments:
min	L	Ind	CG	WG	OG	AnQ	SQ	WC	Prd	SP	TQ	W	O	Lec	RtW	FUp	PQ	CQ	AnQ	MG	1o1	D/V	Adm	W	O	
0 - 2																										
2-4																										
4-6																										

Figure 1. An excerpt of the COPUS coding form (Smith et al., 2013).

Stains et al. (2018) made a step towards meeting the need of measuring active learning pedagogies accurately, and how they shift over time. In their study they evaluated "…STEM teaching practices in North American universities based on classroom observations from over 2000 classes taught by more than 500 STEM faculty members across 25 institutions" (p. 1468). Stains et al. (2018) used COPUS data for their evaluation; this data was chosen because it has been widely used and has been demonstrated to be a valid indicator of instructional practices used in STEM instruction. However, because the frequency of student and instructor behaviors does not inform what strategies were being used, they conducted a latent profile analysis on the following four student behaviors: group work on clicker questions, group work on worksheets, other group work, and asking questions, and the following four instructor behaviors: lecture,

1. Students are Doing	
L	Listening to instructor/taking notes, etc.
Ind	Individual thinking/problem solving. Only mark when an instructor explicitly asks students to think about a clicker question or another question/problem on their own
CG	Discuss clicker question in groups of 2 or more students
WG	Working in groups on worksheet activity
OG	Other assigned group activity, such as responding to instructor question
AnQ	Student answering a question posted by the instructor with rest of class listening
SQ	Student asks a question
WC	Engaged in whole class discussion by offering explanations, opinion, judgment, etc. to whole class, often facilitated by instructor
Prd	Making a prediction about the outcome of demo or experiment
SP	Presentation by student(s)
TQ	Test or quiz
W	Waiting (instructor late, working on fixing AV problems, instructor otherwise occupied, etc.)
O	Other -- explain in comments
2. Instructor is Doing	
Lec	Lecturing (presenting content, deriving mathematical results, presenting a problem solution, etc.
RtW	Real-time writing on board, doc. Projector, etc. (often checked off along with Lec)
FUp	Follow-up/feedback on clicker question or activity to entire class
PQ	Posing non-clicker question to students (non-rhetorical)
CQ	Asking a clicker question (mark the entire time the instructor is using a clicker question, not just when first asked)
AnQ	Listening to and answering student questions with entire class listening
MG	Moving through class guiding ongoing student work during active learning task
1o1	One-on-one extended discussion with one or a few individuals, not paying attention to the rest of the class (can be along with MG or AnQ)
D/V	Showing or conducting a demo, experiment, simulation, video, or animation
Adm	Administration (assign homework, return tests, etc.)
W	Waiting when there is an opportunity for an instructor to be interacting with or observing/listening to student or group activities and the instructor is not doing so
O	Other -- explain in comments

Figure 2. Description of the COPUS codes (Smith et al. 2013).

posting questions, clicker questions, and one-on-one work with students. The authors chose these eight behaviors because "…they were observed with adequate heterogeneity, were not highly correlated with each other, and were likely to be key strategies in active or nonactive learning environments" (p. 1469). The analysis of the eight behaviors resulted in the identification of seven distinctive instructional profile clusters. The seven clusters were categorized as didactic, interactive lecture, or student-centered. The Didactic category includes clusters one and two and revealed at least 80% of class time included lecturing. Clusters three and four make up the Interactive Lecture category and found lectures were enhanced with student-centered activities. The Student-Centered category made up of clusters six, seven, and eight, found large portions of class time spent on student-centered strategies. Their analysis of STEM instructional practice profiles suggests about 55% of classes were taught with didactic practices, about 27% of classes were taught with interactive lecture practices, and about 18% of classes were taught using primarily student-centered methods; which is troubling, given the evidence of the positive impact of student-centered methods, and the institutional and national interest in reform.

Summary

Extensive support for the effectiveness of using active learning techniques to improve student learning has been well demonstrated; particularly in the STEM fields, and biology specifically. The SCALE-UP method incorporates active learning pedagogies into a space that is designed to facilitate effective active learning. Broad evidence indicates that the SCALE-UP method has been successful in enhancing student outcomes.

Review of the literature has shown that classroom design coupled with student-centered, active learning pedagogies can produce student academic gains. Of concern, however, are the methods that have been predominately used, or not used, to arrive at these findings. Theobald and Freeman (2014) demonstrated studies that do not control for student nonequivalence could not be certain the improved student outcomes are a result of differences in student characteristics, or the intervention itself, calling to question the validity of the majority of existing research. Also problematic is the lack of data sources that measure student-centered educational practices in STEM education. Andrews et al. (2011) suggested that instructors who do not have the proper skills and knowledge to use active learning techniques effectively may not produce learning gains. Given the importance of active learning pedagogies to the success of the SCALE-UP method, the measurement and analysis of teaching practices would better inform future studies.

CHAPTER 3. METHODS

The purpose of this study is to examine the impact of a SCALE-UP environment on student achievement in Biology 151, General Biology II, as evidenced by student course grades, while accounting for instructor pedagogy. This study was guided by the following research questions:

1. To what extent does the use of a SCALE-UP classroom impact student grades in Biology 151, General Biology II?
2. How do active learning pedagogies differ between the SCALE-UP classroom and a fixed-seat auditorium?

The setting for this study is a Midwestern public research university that recently initiated a campus-wide effort supporting the increase of active learning on its campus. To encourage this initiative, two large SCALE-UP classrooms (Figure 3), one room seating 135 students, the other seating 99 students, were introduced in January 2016, presenting a new opportunity to offer large introductory courses in SCALE-UP classrooms. The biological sciences department took advantage of the opportunity, moving all of the General Biology I and II sections to SCALE-UP classrooms. Before Spring Semester, 2016, most of these courses were taught in a 391-seat auditorium (Figure 4). The SCALE-UP classrooms at this institution include the following commonly found adaptations from Beichner's original project: the lab component is not included, and student laptops are not provided; personal laptop connections are available.

Research Design

A quasi-experimental design, having a control group (auditorium) and a treatment group (SCALE-UP), was used for this study since the participants were not randomly assigned to the control and treatment groups. Using a mixed methods approach added strength to the findings by allowing a more in-depth understanding; the first research question was answered using quantitative methods, while the second research question was answered using qualitative methods.

Figure 3. SCALE-UP classroom

Figure 4. Fixed-seat auditorium

To answer the first research question, to what extent does the use of a SCALE-UP classroom impact student grades in Biology 151, General Biology II, this exploratory study examined the relationship between the dependent variable of student course grade in Biology 151 and the independent variable of being taught Biology 151 in a fixed-seat auditorium (control group) or a SCALE-UP classroom (treatment group). The independent variables that were tested included college cumulative GPA, major (biology-related or non-biology-related), high school GPA, ACT composite, Biology 150 letter grade (prerequisite for Biology 151), Biology 150 classroom (fixed-seat auditorium/SCALE-UP), gender, ethnicity, citizenship, and Pell eligibility. Controlling for these other independent variables established internal validity; without doing so, an independent variable besides the classroom type could have an impact on the course grade, and the results would be invalid (Theobald & Freeman, 2014).

Research has shown the correlation between the quantity and quality of active learning techniques and the impact on student learning (Andrews et al., 2011; Brooks, 2011; Brooks & Solheim, 2014; Connell et al., 2016; Dori & Belcher, 2005; Felege & Ralph, 2018; Hao et al., 2018; Rogers et al., 2015; Stains et al., 2018); therefore, to answer the second research question, how did active learning pedagogies differ between the SCALE-UP classroom and a fixed-seat auditorium, this study used three sources of data related to active learning methods. The syllabi for the five sections being studied were collected to learn of any shifts to course activities, materials, intended outcomes, or assessments during the period. Secondly, this study requested Classroom Observation Protocol for Undergraduate STEM (COPUS) data to examine what both the instructor and the students were doing in each section. Lastly, an interview with the instructor was also conducted to gain insight relevant to the syallabi and COPUS findings, as well as to learn how the nature and quality of the active learning techniques used in the SCALE-UP classroom compared to the active learning techniques used in the auditorium.

Participants

Institutional student data was collected for undergraduate students who completed the introductory Biology 151 course spring semester 2015 in a 391-seat auditorium. The same data was collected for students who completed the same course spring semesters 2016 (two sections), 2017, and 2018 in a 135-seat SCALE-UP classroom. The sample was delimited to students who took Biology 151 at this institution one time; the students who repeated the course were removed from the analysis to avoid violating the assumption of independence. This population was chosen as they all had the same instructor over a period of four years, as well as the availability of COPUS data and syllabi for that instructor. The instructor followed for this study has been an instructor for twelve years, earning two awards for her active learning techniques during that time. She described her teaching style as active and intentional, using active learning methods even when she taught in the 391-seat auditorium.

Data Collection

Institutional records were requested for students who took Biology 151 spring semesters 2015, 2016 (two sections), 2017, and 2018 from the identified instructor. The independent variables that were tested include college cumulative GPA, major, high school GPA, ACT composite, Biology 150 letter grade (prerequisite for Biology 151), Biology 150 classroom (fixed-seat auditorium/SCALE-UP), gender, ethnicity, citizenship, and Pell eligibility (Connell et al., 2016; Haak et al., 2011; Theobald & Freeman, 2014). Additionally, the independent variable of Biology 151 classroom type was requested to show whether the student completed Biology 151 in a fixed-seat auditorium or a SCALE-UP classroom. The dependent variable, collected from the instructor, was the Biology 151 course grade which was analyzed as the percentage the student earned in the course.

Syllabi for the five sections being studied were collected from the instructor, to analyze the course activities, materials, intended outcomes and assessments over time. COPUS data were collected as part of another project and were shared with me. COPUS is a valid and reliable instrument for documenting what the instructor and students are doing in the classroom (Smith et al., 2013). Data was also obtained directly from the instructor in a follow-up semi-structured interview to gain deeper insight into the data derived from the analysis of the course grades, differences found in the course syllabi, and COPUS data, the differences in teaching practices, and the effectiveness of the SCALE-UP classroom. The semi-structured interview method was chosen to allow for new ideas to be brought up during the interview as a result of what the instructor says. The instructor was asked to describe her teaching approach, how many years she had been using active learning pedagogies, how she prepared for using active learning techniques, how she prepared for teaching in a SCALE-UP classroom, the culture of her department, what the typical classroom experience was for the student in the auditorium and SCALE-UP classroom, describe the active learning techniques used in the auditorium and SCALE-UP classroom over time, describe how she used the structure of the SCALE-UP classroom, elaborate on the differences of the active learning techniques between the two classroom types, describe how the use of Learning Assistants evolved, clarify differences found between the syllabi, explain COPUS findings, explain course grade findings and any other thoughts or feedback she would like to share. The complete list of interview questions is available in Appendix A.

Analysis

An analysis of variance (ANOVA) was initially used to examine whether there was significant variance between the auditorium course grades, SCALE-UP year one course grades, SCALE-UP year two course grades, and SCALE-UP year three course grades. The variance between the terms was found to be significantly different, so the data were analyzed with a post-hoc test to learn where the significant variance occurred. These results were then used to determine how the groups (i.e., auditorium and the various SCALE-UP sections) would be inputted into the subsequent linear regression model.

A multiple linear regression model was used to assess the ability of a SCALE-UP classroom to predict the dependent variable, Biology 151 course grade, after controlling for the influence of the following independent variables: college cumulative GPA, major, high school GPA, ACT composite, Biology 151 classroom (fixed-seat auditorium/SCALE-UP), Biology 150 letter grade (prerequisite for Biology 151), Biology 150 classroom (fixed-seat auditorium/SCALE-UP), gender, ethnicity, citizenship, and Pell eligibility. Backward regression was used to remove the variables that were found to be non-significant, then the analysis was re-run until none of the remaining variables were found to be non-significant in the prediction of the Biology 151 course grade.

The syllabi for each term being studied were analyzed to identify differences among the terms. Specifically, the course description, outcomes, covered content, materials, supports, assignments, and assessments, were compared and key differences were noted for future exploration in the semi-structured interview.

An analysis of the COPUS data was conducted to explore how teaching practices differed between the sections. The data documented the instructor and student classroom behaviors in 2-min intervals during the class session. To interpret the COPUS data, the researcher compared the frequency of the instructor and student behavior codes in each classroom type to identify if there were any notable differences. Lund et al. (2015) uncovered a shortcoming with the original COPUS analysis and suggested dividing the total number of 2-minute time blocks in which a certain code was used by the total number of time periods in which it is observed, rather than dividing the frequency of 2-minute time blocks by the total number of codes that were used, as suggested by Smith et al., (2013). The research used Lund et al.'s (2015) approach to analyzing the COPUS data to reveal frequency of instructor and student behaviors. The COPUS data was further analyzed by identifying an instructor profile, guided by the method used by Stains et al. (2018), for each term; allowing the researcher to learn of shifts in observed classroom student and instructor behaviors. While the number of observations available for analysis in this study was limited, the method used by Stains et al. (2018) provided a framework for the researcher to analyze the frequency of the following student behaviors: group work on clicker questions, group work on worksheets, other group work, and asking questions, and the following four instructor behaviors: lecture, posting questions, clicker questions, and one-on-one work with students.

The semi-structured instructor interview was conducted in-person and was recorded and transcribed for analysis of themes. As part of this analysis, the researcher coded the data to extrapolate the prominent viewpoints of the instructor.

CHAPTER 4. RESULTS

The Student-Centered Active Learning Environment for Undergraduate Programs (SCALE-UP) initiative is costly regarding space, technology, and time; understanding its effectiveness is relevant to anyone considering financing or redesigning their course. The purpose of the study was to examine the impact of a SCALE-UP environment on student achievement in Biology 151, General Biology II, as evidenced by student course grades, while accounting for instructor pedagogy. The study, guided by the following research questions, sought to answer:

1. To what extent does the use of a SCALE-UP classroom impact student grades in Biology 151, General Biology II?
2. How do active learning pedagogies differ between the SCALE-UP classroom and a fixed-seat auditorium?

This chapter presents the results of the analysis of data collected in this study. IBM SPSS Statistics software, version 25, was used to run the quantitative data analysis. The first research question was answered using quantitative methods; specifically, the researcher conducted an analysis of variance followed by multiple linear regression. The second research question was answered using qualitative methods. A comparative analysis was done with the syllabus from each section in the study, a comparison was completed of the behavior codes from the Classroom Observation Protocol for Undergraduate STEM (COPUS) data, and theme-coding was done to analyze the instructor semi-structured interview.

Study Population and Student Characteristics

Institutional data was obtained for students who completed the introductory Biology 151 course spring semesters 2015, 2016 (two sections), 2017, and 2018. Biology 151 spring semester

2015 was scheduled in a 391-seat fixed-seat auditorium while spring semesters 2016 (two sections), 2017, and 2018 were scheduled in a 135-seat SCALE-UP classroom. These groups will be referred to as Aud, SU1 (encompasses both sections from Spring 2016 semester), SU2, and SU3 from this point forward. The sections of Biology 151 chosen for this study were all taught by the same instructor over a period of four years; adding strength was the availability of COPUS data and syllabi for that instructor. The instructor being followed for this study had been an instructor for twelve years, earning two awards for her active learning techniques during that time. She described her teaching style as active and intentional, using active learning methods even when she taught in the 391-seat auditorium.

Characteristics of the student sample are found in Table 1. The initial sample population had 800 students; students who were repeating the course at the same institution were removed to avoid violating the assumption of independence, leaving 784 students. A Biology 151 grade was not earned by eleven students who withdrew before receiving a grade, resulting in a final population of 773 students considered in the statistical analyses for which the dependent variable was course grade (i.e., ANOVA and multiple linear regression). By term, the population breaks down to: 36.9% Aud, 29.2% SU1, 17.0% SU2, and 17.0% SU3. By classroom type, 36.9% of the students took Biology 151 in a fixed-seat auditorium, while 63.1% of the students took the course in a SCALE-UP classroom over the course of three years.

Research Question One

To answer the question, to what extent does the use of a SCALE-UP classroom impact student grades in Biology 151, an analysis of variance (ANOVA) test, post-hoc test, and multiple linear regression analysis were conducted.

Table 1

Student Characteristics (N = 784)

	Auditorium *n* (%)	SCALE-UP Year 1 *n* (%)	SCALE-UP Year 2 *n* (%)	SCALE-UP Year 3 *n* (%)	Total
	289 (36.9%)	229 (29.2%)	133 (17.0%)	133 (17.0%)	784 (100%)
Average					
[a]Biology 151 Grade	81.69%	83.68%	86.00%	86.07%	83.74%
[b]Biology 150 Grade	3.192	3.134	3.445	3.481	3.267
[c]High School GPA	3.511	3.574	3.684	3.671	3.571
[d]Composite ACT	23.94	24.53	25.42	24.89	24.49
[e]College GPA	3.205	3.285	3.540	3.495	3.330
Gender					
Male	146 (50.5%)	120 (52.4%)	39 (29.3%)	59 (44.4%)	364 (46.4%)
Female	143 (49.5%)	109 (47.6%)	94 (70.7%)	74 (55.6%)	420 (53.6%)
[f]Ethnicity					
White	253 (91.7%)	201 (91.0%)	114 (87.7%)	122 (96.8%)	690 (91.6%)
Student of Color	23 (8.3%)	20 (9.0%)	16 (12.3%)	4 (3.2%)	63 (8.4%)
Academic Level					
Freshmen	81 (28.0%)	56 (24.5%)	11 (8.3%)	18 (13.5%)	166 (21.2%)
Sophomore	108 (37.4%)	90 (39.3%)	68 (51.1%)	61 (45.9%)	327 (41.7%)
Junior	52 (18.0%)	47 (20.5%)	39 (29.3%)	32 (24.1%)	170 (21.7%)
Senior	48 (16.6%)	36 (15.7%)	15 (11.3%)	21 (15.8%)	120 (15.3%)
Professional	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.8%)	1 (0.1%)
Major					
Biology	103 (35.6%)	96 (41.9%)	36 (27.1%)	48 (36.1%)	283 (36.1%)
Non-Biology	186 (64.4%)	133 (58.1%)	97 (72.9%)	85 (63.9%)	501 (63.9%)
Pell Eligibility					
Eligible	52 (18.0%)	50 (21.8%)	34 (25.6%)	20 (15.0%)	156 (19.9%)
Non-Eligible	237 (82.0%)	179 (78.2%)	99 (74.4%)	113 (85.0%)	628 (80.1%)

[a]*n* = 773; 11 students did not receive a grade in Biology 151.
[b]*n* = 726; 58 students transferred and did not have a Biology 150 grade on record.
[c]*n* = 746; 38 students did not have a high school GPA on record.
[d]*n* = 727; 57 students did not have an ACT composite score on record.
[e]*n* = 773; 11 students had not yet earned a college GPA at this institution.
[f]*n* = 753; 31 students did not provide their ethnicity.

Analysis of Variance

A one-way between-groups analysis of variance was conducted to determine if significant differences existed in course grades between students enrolled in Aud, SU1, SU2, and SU3. An analysis of variance summary can be found in Table 2. There was a statistically significant difference at the nominal significance level $\alpha = .05$ in the percentage grades earned between terms: $F(3, 769) = 6.0$, $p < .001$. Although reaching statistical significance, the actual difference in mean scores between the groups was small; the effect size, calculated using eta squared, was .02.

Post-hoc comparisons using the Tukey HSD test indicated that the mean percentage grade for the Aud students was not significantly different from the mean percentage grade for the SU1 students, but was significantly different from the mean percentage grade for SU2 and SU3. Further, the mean percentage grade was not found to be significantly different between SU2 and SU3; therefore, the data from those two terms were combined for the purposes of the subsequent regression analysis in order to be considered as one collective group that received the intervention of the SCALE-UP classroom. Since SU1 was not statistically different from the Aud or SU2 and SU3, it was removed from the sample for the regression analysis. Table 3 illustrates the means and standard deviations that were found for each group.

Table 2

One-Way Analysis of Variance Summary Table for the Effects of the Term on the Percentage Grade Earned in Biology 151

Source	*df*	Sum of Squares	Mean Square	*F*	*p*	η^2
Between-group	3	2583.53	861.18	6.008	.000	.02
Within-group	769	110226.44	143.38			
Total	772	112809.97				

Table 3

ANOVA Comparisons of Biology 151 Grade Among AUD, SU1, SU2, and SU3

				Tukey's HSD Comparisons
Group	*n*	Mean	*SD*	Aud *p*-value
Aud	285	81.69	12.37	
SU1	226	83.68	11.01	.242
SU2	132	86.00	13.59	.004
SU3	130	86.07	10.88	.003

Multiple Linear Regression

Additional analysis was needed to detect if these differences were a result of the use of a SCALE-UP classroom, after controlling for the influence of: college cumulative GPA, major, high school GPA, ACT composite, Biology 150 letter grade (letter grades were equated to GPA points for the purpose of analysis; i.e., A = 4.00, B = 3.00, C = 2.00, D = 1.00, F = 0.00), Biology 150 classroom (fixed-seat auditorium/SCALE-UP), gender, ethnicity, citizenship, and Pell eligibility. Biology 151 taught in the Aud was coded as 0, and SU2 and SU3 were combined and coded as 1; SU1 was excluded from the regression analysis. Preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity, multicollinearity or homoscedasticity. The total variance explained by the model was an impressive 65.3%, $F(3, 474) = 297.62$, $p < .001$. Using backward elimination, the final model included three independent variables that were found to be statistically significant in predicting the Biology 151 course grade. College GPA was found to make the strongest unique contribution to explaining the Biology 151 course grade ($\beta = .55$, $p < .001$); next, in order of strength were the Biology 150 grade ($\beta = .20$, $p < .001$), and high school GPA ($\beta = .12$, $p < .001$). Table 4 provides the means, standard deviations, and correlations for the college GPA, Biology 150 grade, and high school GPA predictor variables, and the Biology 151 course grade. Table 5 presents a regression analysis summary of college GPA, Biology 150 grade, and high school GPA in predicting the Biology 151 course grade. Based on the regression results, for every one point increase in the college GPA, the Biology 151 course grade is predicted to increase 11.00 points. For every one point increase in the high school GPA, the Biology 151 course grade is predicted to increase 3.50 points. For every one point increase in the Biology 150 grade (which equates to a full letter grade increase due to the scale used in the analysis), the Biology 151 course grade is predicted to increase 2.96 points. The Biology 151 classroom (auditorium/SCALE-UP) type was not found to be a significant unique contributor ($\beta = .01$, $p = .736$) to the prediction of the Biology 151 course grade. Therefore, this study found that being taught in the SCALE-UP classroom is not a significant predictor of the Biology 151 course grade after controlling for other predictor variables.

Table 4

Means, Standard Deviations, and Intercorrelations for Biology 151 Course Grade and Predictor Variables

Variable	*M*	*SD*	1	2	3
Biology 151 course grade	83.77	12.52	.79	.72	.59
Predictor variable					
1. College GPA	3.36	.63	1.00	.80	.64
2. Biology 150 grade	3.32	.85	.80	1.00	.59
3. High school GPA	3.57	.44	.64	.59	1.00

Table 5

Regression Analysis Summary for Variables Predicting Biology 151 Course Grade

Variable	*B*	*SE B*	*β*	*t*	*p*
College GPA	11.00	.96	.55	11.43	.000
Biology 150 grade	2.96	.68	.20	4.34	.000
High school GPA	3.50	1.02	.12	3.43	.001

Note: $R^2 = .65$ ($N = 547$, $p < .001$).

Research Question Two

To answer the question, how do active learning pedagogies differ between the SCALE-UP classroom and a fixed-seat auditorium, the course syllabus and COPUS data for each section was explored, and an instructor interview was conducted.

Syllabus Comparison

Course syllabi were gathered for all four semesters (Aud, SU1, SU2, and SU3) to investigate how, if at all, active learning pedagogies differed in course design between the auditorium and SCALE-UP environments. Syllabi were examined for differences in content, materials, course activities, and assignments. This comparative analysis revealed that the primary differences were shifts in required course materials, as well as, a shift in course content. Specifically:

- SU1 no longer had the students purchase the textbook access code.
- SU2 no longer used clickers.
- SU2 students were required to purchase carbonless notebooks.
- SU2 used a different textbook.
- SU2 saw a shift in course content.
- SU3 textbook was replaced by an Open Educational Resource (OER) textbook.

These results were then used to inform the semi-structured interview with the instructor in order to best illuminate how the shifts in course activities, materials, and assignments impacted active learning techniques in the various classroom settings.

COPUS

COPUS data was obtained for all four semesters (Aud, SU1, SU2, and SU3) to explore how, if at all, the frequency of observed instructor and student behaviors changed between the auditorium and SCALE-UP classroom environments.

Stains et al. (2018) found that “reliable characterization of instructional practice requires at least four visits” (p. 1469). COPUS observations for this study were limited by having only one observation available during the term Biology 151 was taught in the Aud and three observations for SU1 morning section; the SU1 afternoon and SU2 sections had 12 observations each, and SU3 had 11 observations. Following the framework provided by Stains et al. (2018), a comparison of the frequencies of the following student behaviors: group work on clicker questions, group work on worksheets, other group work, and asking questions, and the following four instructor behaviors: lecture, posting questions, clicker questions, and one-on-one work with students was done. Frequencies of behavior codes were calculated by dividing the total number of 2-minute time blocks in which a certain code was used by the total number of time periods in which it was observed; this method of calculation was suggested by Lund et al. (2015). Figure 5 illustrates the instructional profiles as analyzed by Stains et al. (2018). Figure 6 depicts the frequencies of the same COPUS codes for the instructor followed by this study. At first glance, it may appear the instructor spent most of the class time in the auditorium lecturing; however, at just 58% of the time, this falls into the Student-Centered instructional profile as illustrated by Stains et al. (2018) in Figure 5. In comparison to the three instructional profiles identified by Stains et al. (2018), the COPUS analysis for the instructor of this study indicates she had a Student-Centered instructional profile; both when she taught Biology 151 in the auditorium, as well as in the SCALE-UP classroom.

In addition to identifying the instructor's instructional profile, the comparative analysis of the COPUS data aimed to identify how active learning pedagogies may have been different between the auditorium and the SCALE-UP classroom. As concluded earlier, the instructor was found to be Student-Centered in both classroom environments; what did change, however, was the percentage of time the instructor lectured, ranging from a peak of 58% in the auditorium to a low of 29% in the SCALE-UP classroom, student clicker group discussions decreased in the SCALE-UP classroom, ranging from a high of 29% in the auditorium to a low of 1% in the SCALE-UP classroom. Upon further analysis, the researcher found that student questions also decreased in the SCALE-UP classroom. Meanwhile, group worksheets, other group work, instructor questions, and instructor one-on-one work increased in the SCALE-UP classroom.

These changes are illustrated in Figure 6 and the results further informed the instructor interview, as described below.

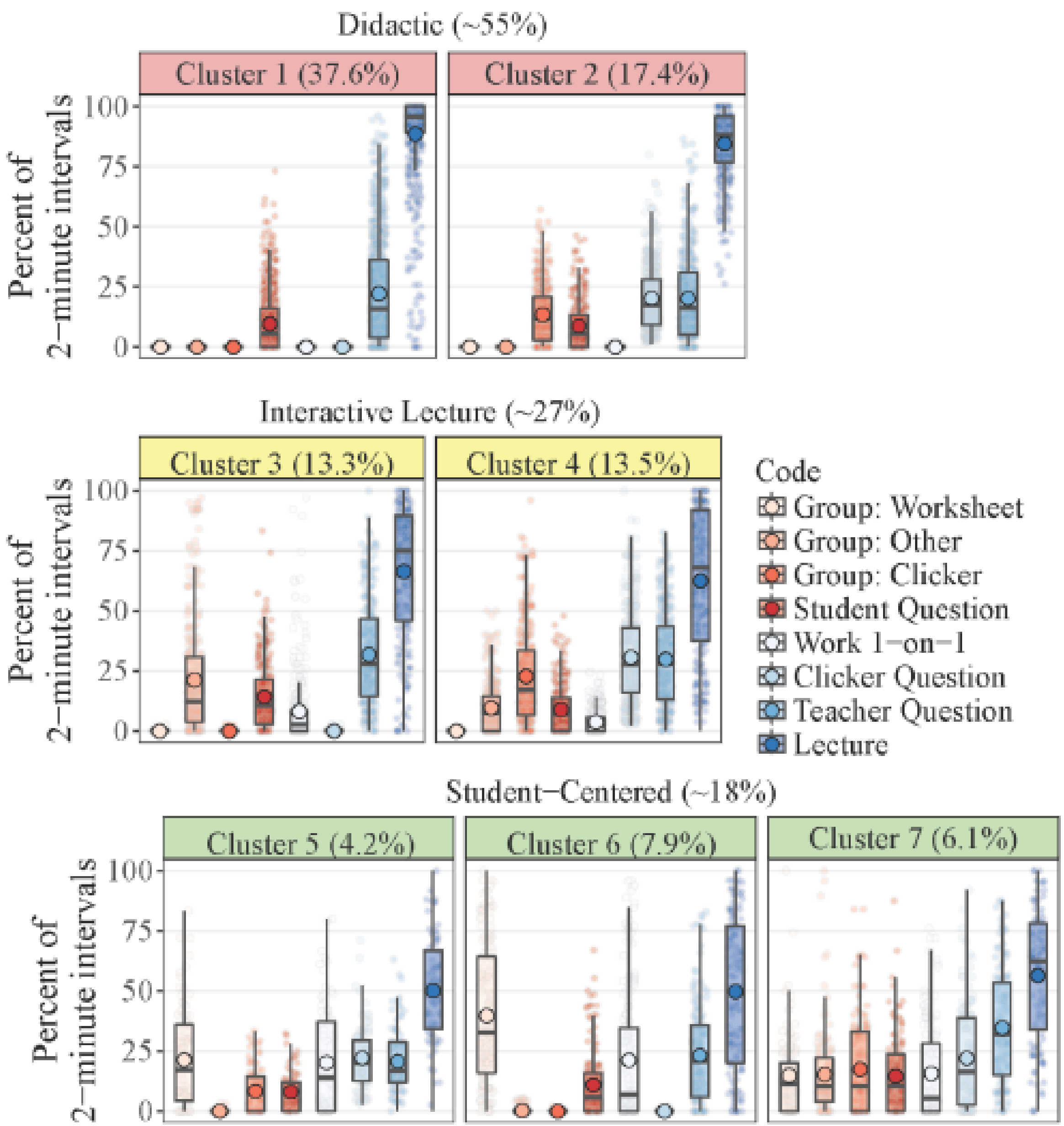
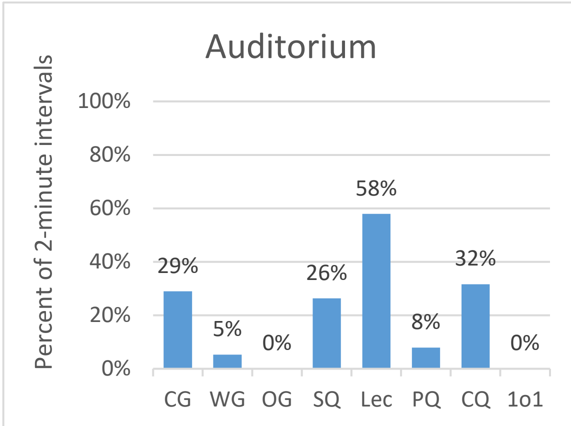


Figure 5. Instructional profiles (Stains et al., 2018).



Behavior Codes	
CG	Group: Clicker
WG	Group: Worksheet
OG	Group: Other
SQ	Student Question
Lec	Lecture
PQ	Teacher Question
CQ	Clicker Question
1o1	Work 1-on-1

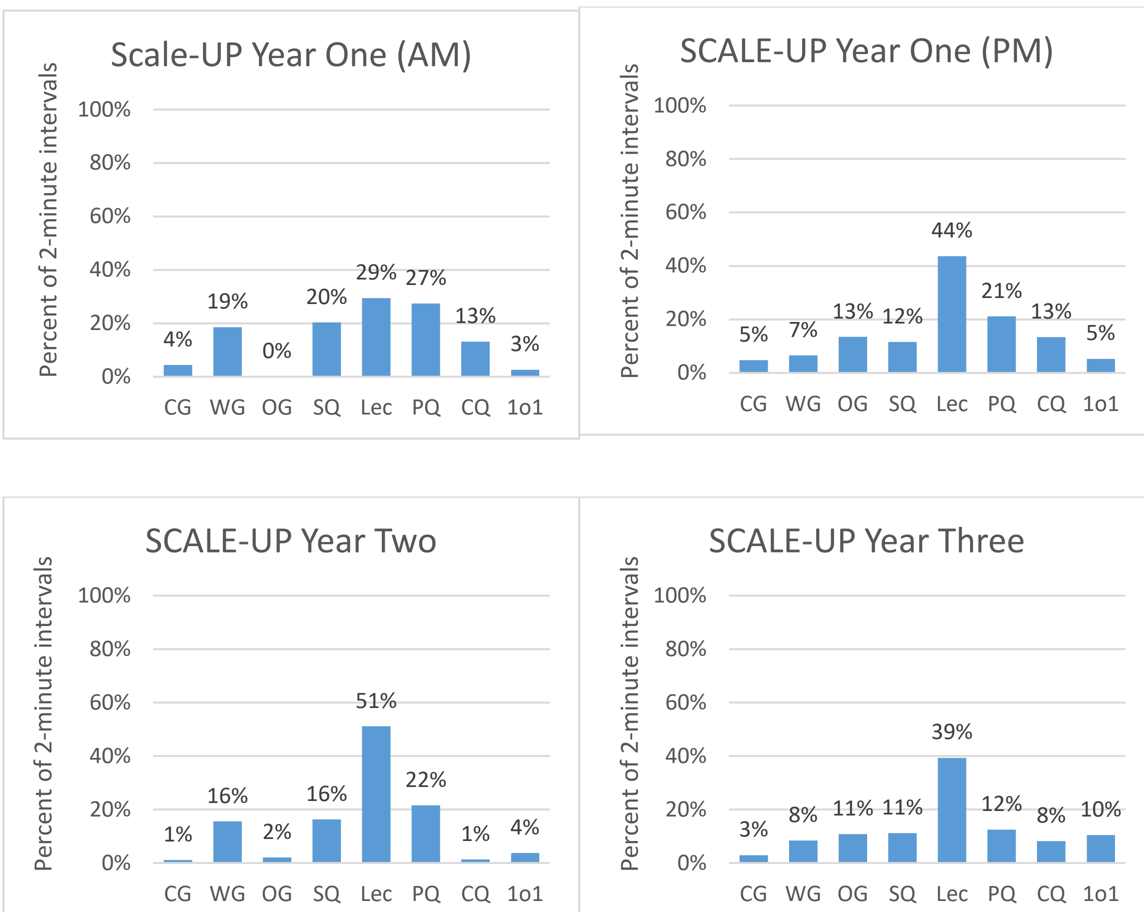


Figure 6. COPUS behavior code frequencies by Biology 151 section.

Instructor Semi-Structured Interview

Taken together, the analysis of the syllabi and COPUS data provided an initial overview of how active learning pedagogies differed between the SCALE-UP classroom and the fixed-seat auditorium. To build on these initial insights, a semi-structured interview was conducted with the instructor to gain further insight into the ways active learning pedagogies shifted between the auditorium and SCALE-UP classrooms. The interview was recorded and transcribed for analysis of themes. As part of this analysis, the researcher coded the data to assist with capturing and interpreting the instructor's viewpoint. During the first cycle of coding, the researcher assigned codes and sub-codes to salient sections of data, along with analytic memos intended to help make connections among emergent themes. The researcher assigned codes intended to illuminate key active learning strategies that were embedded in the course design, as well as draw attention to how they may have changed in the different classroom types. For example, several interview excerpts were coded as 'problem solving' with sub-codes related to 'shoulder buddies' in the auditorium setting, while the sub-code 'group work' was used in the SCALE-UP setting to help draw attention to the different ways active learning manifested in these spaces. To facilitate further analysis, during second cycle coding, the researcher analyzed the codes and their relevant sections of the transcript, to identify major thematic categories, such as 'instructor passion,' 'instructor development,' and 'classroom structure.' Mind maps were drawn to identify connections and narrow the resultant thematic categories. This exercise was found to be powerful, leading to the forming of concepts, and ultimately the development of an assertion that answered the second research question, how did active learning pedagogies differ between the SCALE-UP classroom and a fixed-seat auditorium. For example, it became obvious that instructor passion, development, and classroom structure were the triad of active learning pedagogies in this study. After several iterations, the visual display, depicted in Figure 7, was drawn to show how the concepts interrelate. Additionally, key quotes from the instructor were identified to provide helpful illustrations of the concepts that emerged from this analysis.

An outcomes-focused approach. The instructor's overall approach to teaching, both in the auditorium and in the SCALE-UP classroom, were captured to provide a comprehensive understanding of the similarities and differences in active learning pedagogies. The instructor is passionate about the student outcomes that result from taking her course. Not only is she passionate about her students learning the necessary skills required for the course, which includes demonstrating mastery through explaining concepts and analyzing problems, she also strives to instill a love and fascination of biology, along with a desire for lifelong learning. These outcomes inform her course design, as illustrated in Figure 7.

The instructor stated that she "always knew the importance of letting students have time in class to process and work on higher order problems." She gained this perspective as a teaching assistant while in graduate school where she worked "under two good role models, who were very progressive, using active learning techniques before they were popular, it was just the natural way they taught." To further advance her knowledge of using active learning techniques, she attended two classes, during graduate school, in the "Preparing Future Faculty" Program, which were focused on active learning techniques. Since she began teaching as faculty, she has been avid about continuing her pedagogical development by regularly attending institutes, workshops, and conferences. Also helpful is that the Biological Sciences department where she teaches has a culture that supports active learning pedagogies, and as a Professor of Practice her position is 80% teaching which gives her more time to plan her teaching practices. Passion, professional development, and departmental support play an important role in her course design, as illustrated by the top portion of Figure 7.

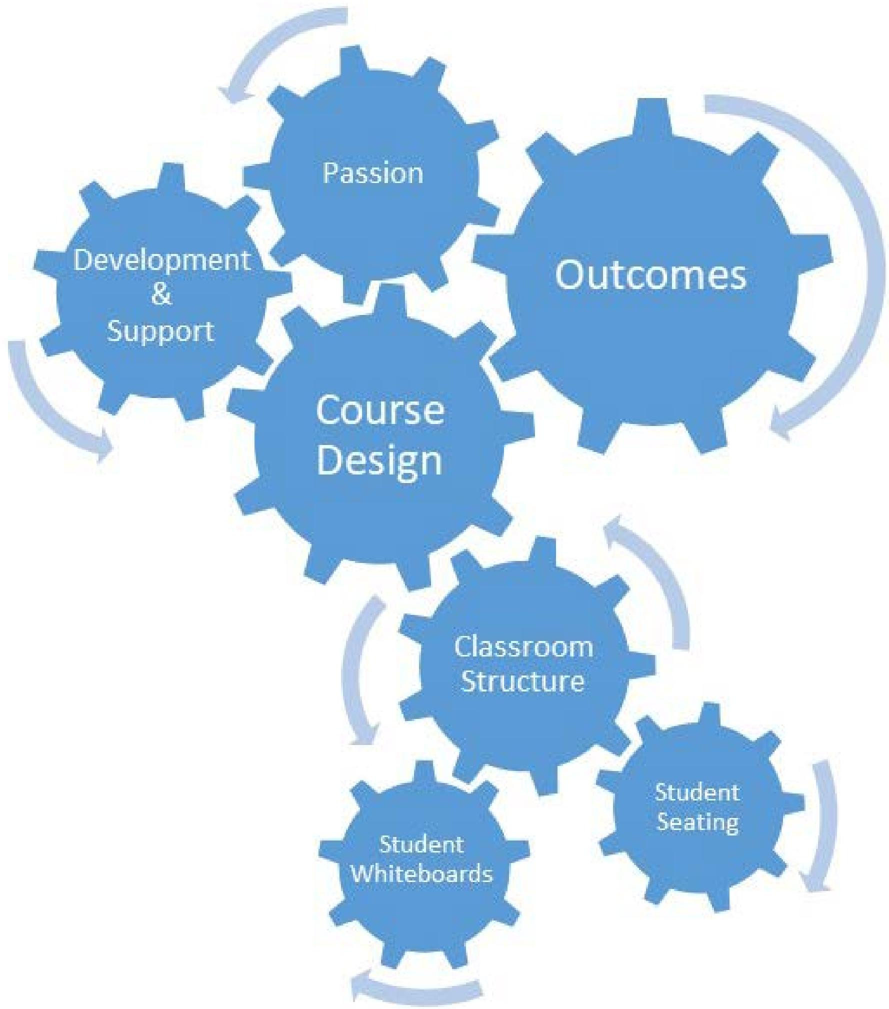


Figure 7. Visual representation of concepts

Similarities. Similarities in course design and active learning pedagogies were found between the auditorium and the SCALE-UP classrooms. The instructor's course design is based heavily on backward design. When designing her course she thinks about what it is she wants her students to be able to accomplish, and then what she has to do in class so that her students will be able to apply their knowledge to master the objective. She uses a flipped classroom approach to make the most of class time. Students are given assignments that include either readings or videos, along with problems that require they apply the knowledge they gained. During class time there are mini-lectures that describe complex topics and guided practice for solving higher-level problems. Similar higher-order problems are assigned as homework for students to attempt to solve on their own, without support.

It became clear, as the instructor shared what a typical class would be like in the auditorium compared to what a typical class would be like in the SCALE-UP classroom, that she teaches using a student-centered approach, regardless of the classroom structure. This was also supported by the COPUS data that showed she engaged students in their learning using active learning techniques such as ‘group clicker discussions’ and ‘group worksheets.’

Differences. Also evident were clear differences in active learning techniques that existed because of the enhancements of the SCALE-UP classroom, namely the 9-seat round student tables and the student group whiteboards, illustrated in the bottom portion of Figure 7. This was demonstrated by the following exercises that were described as typical in the SCALE-UP classroom, that were not possible in the auditorium:

- SCALE-UP classroom students are instructed to review their homework problems, compare their answers with the students at their table, and determine what answer will be given by the table collectively, earning group quiz points. During this exercise, students are learning from each other and figuring out where mistakes were made. While the table discussions are taking place, the instructor walks around the room to check if there is anything that keeps coming up at several tables as being problematic; if so, she will provide a mini-lecture to clear the misunderstanding. In the auditorium, the instructor would have students talk with a “shoulder buddy” to do group work, which according to her did not produce nearly the same group interactions and discussions.

- SCALE-UP students are given a worksheet to work on as a group at their table; they are instructed to put their answers on their group whiteboard. The instructor and her Learning Assistants are able to walk around and provide instant feedback and correction, groups are then able to change their answer. In the auditorium, there is no way to know who is getting it wrong, or if there are pockets of students who do not understand. While students are working with their "shoulder buddies" the instructor would tell them to flag down her, or the Learning Assistants, if they need help; the students near the aisles would receive help, while the students who were towards the center of the 30-seat rows would not receive any help. Also observed in the auditorium were students who chose to work alone rather than with a "shoulder buddy."

The following is an excerpt that was taken from the transcript, in relation to teaching in the auditorium:

> *I would encourage students to work with buddies, and there were pockets all over that would be working with buddies, and those students tended to do really good in class. But I think the students that maybe needed the interaction the most, were probably the ones that were least likely to interact. Whereas if you are at a table of nine, there's no place to hide. In the big auditorium you don't know who's getting it wrong; you don't know if there are pockets of students who still are not understanding it.*

The instructor used a student-centered approach, using active learning pedagogies, in both the auditorium and the SCALE-UP classroom; however, the structure of the SCALE-UP classroom allowed for better quality group work, peer interactions, and instant feedback, which were not possible in the structure of the auditorium. Indicative of increased learning, the instructor has found that the attendance of the after-class work sessions, offered to students who need additional help, has sharply decreased since teaching in the SCALE-UP classroom; yet, their grades have not decreased.

The instructor was asked to illuminate the differences noted in the syllabi and COPUS data, along with the implications of those differences for the active learning environment of the various course sections. While in the auditorium, the instructor required the students to purchase the textbook access code for pre-class quizzes and homework assignments. Beginning with SU1 the instructor quit having the students purchase the textbook access code because the quizzes and homework assignments were, she felt, too simple, they did not require application of knowledge; the student could simply “Google” the answer. She replaced the publisher-provided assessment tools with her own worksheets. During this term, the instructor also replaced clickers with carbonless notebooks, allowing for more open-ended problems rather than multiple choice clicker questions. These problems were discussed in groups at their round tables. Carbonless notebooks were used so that the students could hand in one copy of the problem to the instructor while being able to hold on to the other copy, having the ability to review later. The shift from clickers to carbonless notebooks occurred for the same reason she quit using the textbook access code; allowing her to assess a deeper understanding of the content. This change was evident in the COPUS findings; the ‘clicker questions asked by the instructor’ and ‘student clicker group discussions’ decreased in the SCALE-UP classroom, while there was an increase in ‘group worksheets’ and ‘other group work.’ The instructor noted the shift to more open ended problems, rather than multiple choice questions, likely made it more difficult for students to earn the same grade they could have earned being graded on multiple choice assessments, because students were required to apply the learned knowledge.

Starting SU2, a different textbook was chosen after a departmental committee made the decision to swap certain Biology 151 course topics with Biology 150 course topics. The instructor noted this change in content to the Biology 151 course likely made the course more difficult (and, thus, more difficult for students to earn the same grade they could have earned before the course content changed) given the challenging nature of certain topics – such as cellular and molecular topics – that were shifted to Biology 151. The SU3 change from a commercial textbook to an open educational resources textbook was done in an effort to save students money. The instructor does not believe this would have had an impact on the results of this study.

Insights into the COPUS findings, including the frequency of various classroom interactions, were shared by the instructor who was surprised by an increase in 'instructor questions' in the SCALE-UP classroom, found by COPUS, as she did not feel there had been an increase. A possible explanation offered was that because she, at times, puts questions on a slide rather than handing out a worksheet, maybe those questions have been coded as 'instructor questions'; however, when she does these activities the students are told to discuss the questions as a group; if this is the case, these scenarios should have been coded as group worksheets. The instructor explanation for the 'student questions' decreasing in the SCALE-UP classroom is due to the sharp increase in peer learning at the round tables, as well as the real-time corrections and help given while students are working at the whiteboards. The increase of instructor 'one-on-one work' has occurred because the round student tables in the SCALE-UP classroom allow for this type of interaction while the 391 fixed-seat auditorium does not.

Conclusion

The results of this study indicated that being taught in the SCALE-UP classroom is not a significant predictor of the Biology 151 course grade. Active learning pedagogies differed between a SCALE-UP classroom and a fixed-seat auditorium. The instructor of this study was already using active learning pedagogies as much as possible, while she taught in an auditorium; however, the structure of the SCALE-UP classroom allowed her pedagogies to evolve. The difference could be summarized by two words: cultivates quality. The 9-seat round tables allowed the instructor to increase group work and peer learning. Group work could be completed in varying group sizes ranging from two to nine. The instructor-to-student, and student-to-student, interactions increased substantially. The round tables and the student whiteboards allow the instructor to provide student groups with real-time feedback as she walks around the classroom during group work exercises. The confluence of factors that may have had an impact on the results will be further discussed in the next chapter.

CHAPTER 5. DISCUSSION

As higher education strives to prepare today's college students for the twenty-first-century workforce, active learning has experienced a surge of popularity in recent years. This surge is a result of active learning strategies being deemed indisputably more effective for student learning compared with traditional pedagogies (Freeman et al., 2014; Prince, 2004); particularly in the STEM fields. The importance of reforming STEM education practices to include active learning techniques has been demonstrated by several national reports such as the American Association for the Advancement of Science, 2011; the National Research Council, 2015; and the President's Council of Advisors of Science and Technology, 2012. However, the preponderance of active learning studies that measure student learning gains have had their validity questioned for not controlling for student characteristics across groups (Theobald & Freeman, 2014). An active learning tool that has been gaining popularity has been the Student-Centered Active Learning Environment for Undergraduate Programs (SCALE-UP) approach. This approach, which encourages student-centered active learning, is expensive regarding space, technology, and time. Pedagogy is the lynchpin of this room working (Beichner et al., 2007), yet many existing studies do not account for instructor pedagogy. One of the challenges of researching the impact of active learning techniques and the SCALE-UP method is that there are no guidelines for measuring effective teaching practices (Stains et al., 2018).

The purpose of this study was to examine the impact of a SCALE-UP environment on student achievement in Biology 151, General Biology II, as evidenced by student course grades, while accounting for instructor pedagogy. This study sought to answer the following research questions:

1. To what extent does the use of a SCALE-UP classroom impact student grades in Biology 151, General Biology II?
3. How do active learning pedagogies differ between the SCALE-UP classroom and a fixed-seat auditorium?

This chapter will present an integrated discussion of study findings, as well as the implications of the results and associated study limitations. Following will be recommendations for further areas of research on the effectiveness of the SCALE-UP classroom.

Impact of a SCALE-UP Environment on Student Grades

This study supports the assertion made by Theobald and Freeman (2014) that when student characteristics across groups are not controlled for, the results could be incorrect. The ANOVA analysis found that the SCALE-UP classroom had a significant impact on student grades; however, once multiple linear regression controlled for several student characteristics, the SCALE-UP classroom was removed from the final model of predictor variables. This study found that the SCALE-UP classroom did not have a direct impact on student grades in Biology 151.

Confounding Factors

The results of this study offer an interesting counterpoint to the majority of studies investigating the impact of SCALE-UP environments on student learning, such as those offered by Beichner (2008), Beichner et al. (2003), Beichner et al. (2007), Brooks (2011), Brooks & Solheim (2014), Dori and Belcher (2005), Felege and Ralph (2018), Hao et al. (2018), and Rogers et al. (2015). During the interview, the instructor revealed several important points for consideration in interpreting these surprising results. First, the Biology 151 course content was substantively changed between SCALE-UP year one and SCALE-UP year two; the instructor notes the topics that were added to Biology 151 are topics that traditionally have been difficult for students to comprehend. Given this observation, it would be logical to expect the Biology 151 grades to go down in subsequent semesters. This, however, was not the case in this study. Furthermore, with the SCALE-UP classroom structure and size being more amenable to worksheets that require the application of knowledge, over simply remembering knowledge, there was an increase in that type of assessment, as evidenced by course syllabi. This shift required students to gain a deeper understanding of the content, which would make it difficult for students to earn the same grade they could have earned being graded on simple assessments; critically, a limitation of this study was it compared grades as the dependent variable rather than knowledge acquisition because of the unavailability of validated content knowledge for the student population. Stoltzfus and Libarkin (2016) analyzed validated content knowledge as the dependent variable in their study and argued it is a better source for measurement of student learning. Suggestive of increased learning, the instructor has found that the attendance of the after-class work sessions, offered to students who need additional help, has sharply decreased since teaching in the SCALE-UP classroom; yet, their grades did not decrease. Taken together, the limitations of the course content and assessment type becoming more difficult, coupled with the finding that the Biology 151 course grades did not go down, are noteworthy.

Comparatively examining the student characteristics in Table 1, specifically their median composite ACT score, college GPA, high school GPA, and Biology 150 grade, uncovered the academic preparation of students entering the instructor’s later sections (SU2 and SU3) was higher than the academic preparation of students in earlier sections (Aud and SU1). This was reaffirmed by the course instructor who, in her interview, noted she had observed the students in later terms seemed more academically prepared than those in earlier terms. The higher the academic preparation of students entering the course, the less room there is for improved learning gains. Haak et al. (2011) used a regression model in a study of 3,338 students and found that increasing structure and active learning in an introductory biology course improved the performance of all students, and reduced the achievement gap of disadvantaged students. A similar study conducted by Freeman et al. (2007) found "introductory biology students benefit from highly structured active-learning environments and that highly structured course designs may have a particular benefit for students who are at high risk of failing the course" (p. 137). The above studies, along with a suggestion from the instructor to analyze high-risk students and low risk students separately, may uncover a benefit not measured by this study and is an important area for future research.

Further, the increased performance in Biology 150 deserves further analysis – especially given it was a significant predictor of the Biology 151 course grade, and shifted to a SCALE-UP classroom in a similar timeframe. Students who took Biology 151 spring semesters 2017 (SU2) and 2018 (SU3) were much more likely to have taken Biology 150 in the SCALE-UP environment fall semesters 2016 and 2017. Beichner et al. (2008) found performance in the second-semester physics class had improved following participation in the first-semester SCALE-UP physics class, whether the second-semester course was taught in a lecture-based class or SCALE-UP. Although there was a lack of significance found from regression analysis on the impact of the SCALE-UP classroom on Biology 151 course grades, there may have been an impact on the Biology 150 course grades.

Contrasting Active Learning Pedagogies: Auditorium and SCALE-UP

Being an award-winning active learning enthusiast, even while teaching in the auditorium, the instructor's active learning techniques were found to be similar between the

Auditorium and SCALE-UP environments. Teaching practices are impacted by the characteristics of the classroom, as well as the instructor (Cotner et al., 2013, Knaub et al., 2016). What was very different was the amount of student-to-student and instructor-to-student interactions; which were not possible to achieve with the structural constraints of the auditorium. The structure of the SCALE-UP classroom allowed her active learning pedagogies to evolve in ways that encouraged higher level learning through social constructivism. Social constructivism emphasizes that learning is constructed in a social context as individuals find meaning that is applicable to their experiences (Vygotskiĭ & Cole, 1978). Most notable, the 9-seat round tables allowed the instructor to greatly increase group work and peer learning. Furthermore, group work could be completed in varying group sizes ranging from two to nine. Adding additional value, the round tables and the student whiteboards allow the instructor to provide student groups with real-time feedback, as she walked around the classroom during group work exercises. The instructor noted the round student tables and whiteboards are important for facilitating the acquisition and application of content knowledge.

A shortcoming of the COPUS data was that there was only one observation available for the term taught in the auditorium. According to Stains et al. (2018), a "reliable characterization of instructional practice requires at least four visits" (p. 1469). Due to this limitation, the COPUS data was analyzed qualitatively rather than quantitatively and was triangulated by what the instructor reported when she described her classes.

Instructor Benefit

Instructors may experience a sense of satisfaction, or even feel professionally rewarded, when given the opportunity to teach their course in a SCALE-UP classroom. Having students that are much more engaged in the learning may invoke feelings of instructor gratification. For example, the instructor expressed how she could never go back to teaching Biology 151 in an auditorium again, after having the experience of teaching it in a SCALE-UP classroom. The enthusiasm in her voice as she discussed the experience of teaching in the SCALE-UP classroom was evident.

Recommendations for Future Research

With the potential of increasing student learning, yet the high costs attached to the implementation and upkeep of the SCALE-UP classroom, it is important for research of its effectiveness to be done with high validity, and reduced limitations. This study was completed with high validity, accounting for student characteristics across groups, and instructor pedagogy. However, as with all research, there were several key limitations that can be addressed in future studies. Future studies should control for course content, ensuring it does not shift during the period being studied, and use validated content knowledge as the measurement of student learning.

Past research has shown that performance in a second-semester course had improved following participation in the first-semester SCALE-UP course, whether the second-semester course was taught in a lecture-based class or SCALE-UP (Beichner, et al., 2008). Future research should be done to investigate the impact of a first-semester course being taken in a SCALE-UP classroom on the performance of the second-semester course, whether the second-semester course was taught in a lecture-based class or SCALE-UP. As noted in Table 1, the Biology 150 grade was substantially higher during SCALE-UP years two and three. For this student population, Biology 150 was moved to a SCALE-UP classroom beginning fall semester of SCALE-UP year two; the year the Biology 150 grades of those entering Biology 151 increased.

A narrowing of the achievement gap for underrepresented populations who take a course in a SCALE-UP classroom has been demonstrated in previous research (Freeman et al., 2007, Haak et al., 2011). Future research should be undertaken that adds focuses on this, oftentimes, unmeasured benefit.

It may be helpful for future studies to compare the impact on student learning between a SCALE-UP classroom, and an active learning classroom that has 9-seat round tables and whiteboards for each student group, without the student technology installed; this would greatly reduce the cost of the SCALE-UP classroom, yet facilitate a student-centered, active learning approach. This would be a valuable follow-up to a study that found student achievement was the same whether they were in a high technology SCALE-UP classroom or in a low technology SCALE-UP classroom (Sonreal & Wyse, 2017).

In addition to the potential benefits for students, future research could evaluate the potential impact teaching in a SCALE-UP classroom has on the instructor. The degree of satisfaction, and/or reward, felt by the instructor could result in positive outcomes for the instructor and student alike.

Overall, due to the limited availability of major research studies that account for student characteristics across groups, and instructor pedagogy, other institutions implementing a SCALE-UP classroom would benefit from doing similar studies.

Final Conclusion

SCALE-UP classrooms continue to spread worldwide, as the majority of the current research indicates they are effective in improving student learning. The SCALE-UP initiative is costly regarding space, technology, and time. The results of this study, which found the SCALE-UP approach does not have a direct impact on Biology 151 course grades, may dissuade university administrators from funding the high cost of a SCALE-UP classroom, or faculty from making the time investment to learn how to use student-centered teaching methods and restructure their course. However, serious consideration should be given to the confounding factors, which help illuminate the surprising results of this study.

REFERENCES

American Association for the Advancement of Science. (2011). Vision and change in undergraduate biology education: A call to action, final report. Washington, D.C. Retrieved from http://visionandchange.org/files/2011/03/Revised-Vision-and-Change-Final-Report.pdf

Andrews, T., Leonard, M., Colgrove, C., & Kalinowski, S. (2011). Active learning not associated with student learning in a random sample of college biology courses. *CBE Life Sciences Education, 10*(4), 394–405. Retrieved from https://doi.org/10.1187/cbe.11-07-0061

Bada, S. O., & Olusegun, S. (2015). Constructivism learning theory: A paradigm for teaching and learning. *Journal of Research & Method in Education, 5*(6), 66-70. Retrieved from: https://pdfs.semanticscholar.org/1c75/083a05630a663371136310a30060a2afe4b1.pdf

Bailey, K. E. (2018). Transforming undergraduate STEM education: Reforming classrooms by training current and future faculty (Order No. 10809552). Available from ProQuest Dissertations & Theses Global. (2042912413). Retrieved from https://ezproxy.lib.ndsu.nodak.edu/login?url=https://search-proquest-com.ezproxy.lib.ndsu.nodak.edu/docview/2042912413?accountid=6766

Beichner, R., Bernold, L., Burniston, E., & Dail, P. (1999). Case study of the physics component of an integrated curriculum. *American Journal of Physics, 67*(7), S16–S24. Retrieved from http://search.proquest.com/docview/216698790/

Beichner, R. (Ed.). (2008, February 15). SCALE-UP: Student-centered active learning environment for undergraduate programs. An Invited White Paper for the National Academy of Sciences.

Beichner, R.J (2014). History and evolution of active learning spaces. *New Directions for Teaching and Learning, (137)*, 9–16.

Beichner, R. J., & Saul, J. M. (2003). Introduction to the SCALE-UP (student-centered activities for large enrollment undergraduate programs) project. Proceedings of the International School of Physics ‘‘Enrico Fermi,’’ Varenna, Italy. Retrieved from https://projects.ncsu.edu/PER/Articles/Varenna_SCALEUP_Paper.pdf

Beichner, R. J., Saul, J. M., Abbott, D. S., Morse, J. J., Deardorff, D. L., Allain, R. J., … Risley, J. S. (2007). The student-centered activities for large enrollment undergraduate programs (SCALE-UP) project. *Research-Based Reform of University Physics* (1). Retrieved from http://www.compadre.org/Repository/document/ServeFile.cfm?ID=4517&DocID=183

Brooks, D. C. (2011). Space matters: The impact of formal learning environments on student learning. *British Journal of Educational Technology, 42*(5), 719–726. Retrieved from https://doi.org/10.1111/j.1467-8535.2010.01098.x

Brooks, D. C., & Solheim, C. A. (2014). Pedagogy matters, too: The impact of adapting teaching approaches to formal learning environments on student learning. *New Directions for Teaching and Learning, 137,* 53-61. doi: 10.1002/tl.20085

Chickering, A. W., & Gamson, Z. F. (1987, March). Seven principles for good practices in undergraduate education. *AAHE Bulletin*, *39*(7), 3-7. Retrieved from http://www.aahea.org/articles/sevenprinciples1987.htm

Connell, G., Donovan, D., & Chambers, T. (2016). Increasing the use of student-centered pedagogies from moderate to high improves student learning and attitudes about biology. *CBE Life Sciences Education, 15*(1). Retrieved from https://doi.org/10.1187/cbe.15-03-0062

Cotner, S., Loper, J., Walker, J. D., & Brooks, D. C. (2013). “It’s not you, it’s the room” – Are the high-tech, active learning classrooms worth it? *Journal of College Science Teaching, 42*(6), 82-88. doi: 10.2505/4/jcst13_042_06_82

Dewey, J. (1897). My pedagogic creed. *School Journal, 54*, 77-80. Retrieved from http://dewey.pragmatism.org/creed.htm

Dewey, J., & Dewey, E. (1915). *Schools of to-morrow*. New York, NY: E. P. Dutton and Company.

Dori, Y. J., & Belcher, J. (2005). How does technology-enabled active learning affect undergraduate students' understanding of electromagnetism concepts? *Journal of the Learning Sciences, 14*(2), 243-279. doi:10.1207/s15327809jls1402_3

Felege, C. J., & Ralph, S. G. (2018) Evaluating the efficacy of a student-centered active learning environment for undergraduate programs (SCALE-UP) classroom for major and non-major biology students, *Journal of Biological Education*. doi: 10.1080/00219266.2018.1447001

Foote, K. T., Neumeyer, X., Henderson, C., Dancy, M. H., & Beichner, R. J. (2014, November 26). Diffusion of research-based instructional strategies: The case of SCALE-UP. *International Journal of STEM Education, 1*(10). doi: 10.1186/s40594-014-0010-8

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014, June 10). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, 111*(23), 8410-8415. doi: 10.1073/pnas.1319030111

Freeman, S., O’Connor, E., Parks, J., Cunningham, M., Hurley, D., Haak, D., … Wenderoth, M. (2007). Prescribed active learning increases performance in introductory biology. *CBE*

Life Sciences Education, *6*(2), 132–139. Retrieved from https://doi.org/10.1187/cbe.06-09-0194

Gierdowski, D. (2012). “Studying learning spaces: A review of selected empirical studies.” In R. Carpenter (Ed.) Cases on Higher Education Spaces. Hershey, PA: IGI Global

Haak, D., HilleRisLambers, J., Pitre, E., & Freeman, S. (2011). Increased structure and active learning reduce the achievement gap in introductory biology. *Science (New York, N.Y.), 332*(6034), 1213–1216. https://doi.org/10.1126/science.1204820

Hake, R. (1998). Interactive-engagement vs. traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*(1), 1-26. Retrieved from http://files.eric.ed.gov/fulltext/ED441679.pdf

Hao, Q., Barnes, B., Wright, E., & Kim, E. (2018). Effects of active learning environments and instructional methods in computer science education. *In Proceedings of the 49th ACM Technical Symposium on Computer Science Education (SIGCSE '18)*. ACM, New York, NY, USA, 934-939. DOI: https://doi.org/10.1145/3159450.3159451

Hunley, S., & Schaller, M. (2009). Assessment: The key to creating spaces that promote learning. *EDUCAUSE Review*, *44*(2), 26-35. Retrieved from https://er.educause.edu/articles/2009/3/assessment-the-key-to-creating-spaces-that-promote-learning

Knaub, A., Foote, K., Henderson, C., Dancy, M., & Beichner, R. (2016). Get a room: the role of classroom space in sustained implementation of studio style instruction. *International Journal of STEM Education*, *3*(1), 1–22. https://doi.org/10.1186/s40594-016-0042-3

Knight, J. K., & Wood, W. B. (2005). Teaching more by lecturing less. *Cell biology education, 4*(4), 298-310. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1305892/pdf/i1536-7509-4-4-298.pdf

Liberal Education & America's Promise. (2007). College learning for the new global century. *Association of American Colleges and Universities.* Retrieved from http://www.aacu.org/sites/default/files/files/LEAP/GlobalCentury_final.pdf

Lund, T., Pilarz, M., Velasco, J., Chakraverty, D., Rosploch, K., Undersander, M., & Stains, M. (2015). The best of both worlds: Building on the COPUS and RTOP observation protocols to easily and reliably measure various levels of reformed instructional practice. *CBE Life Sciences Education, 14*(2). Retrieved from https://doi.org/10.1187/cbe.14-10-0168

Marx, J., & Cummings, K. (2007). Normalized change. *American Journal of Physics, 75*(1), 87. Retrieved from https://doi.org/10.1119/1.2372468

McCarthy, J. P., & Anderson, L. (2000). Active learning techniques versus traditional teaching styles: Two experiments from history and political science. *Innovative Higher Education, 24*(4), 279-294. Retrieved from http://robert-vroman.com/resources/ Avtive%20Learning%20Techniques%20vs%20Traditional%20Teaching%20Styles.pdf

Michael J. (2006). Where's the evidence that active learning works? *Adv Physiol Educ 30*, 159-167. Retrieved from https://www.physiology.org/doi/pdf/10.1152/advan.00053.2006

National Academies of Sciences, Engineering, and Medicine. (2018). Indicators for monitoring undergraduate STEM education. Washington, DC: The National Academies Press. https://doi.org/10.17226/24943.

National Research Council. (2003). BIO2010: Transforming undergraduate education for future research biologists. Washington, DC: The National Academies Press. https://doi.org/10.17226/10497

National Research Council. (2015). Reaching students: What research says about effective instruction in undergraduate science and engineering. Washington, DC: The National Academies Press. Retrieved from https://doi.org/10.17226/18687

President's Council of Advisors of Science and Technology. (2012). Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering and mathematics. Washington, DC: U.S. Government Office of Science and Technology.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, *93*(3), 223–231. Retrieved from https://ezproxy.lib.ndsu.nodak.edu/login?url=https://search-proquest-com.ezproxy.lib.ndsu.nodak.edu/docview/217960253?accountid=6766

Rogers, M., Keller, L. D., Crouse, A., Price, M. F. (2015). Implementing comprehensive reform of introductory physics at a primarily undergraduate institution: A longitudinal case study. *Journal of College Science Teaching*, *22*(3), 82-90. Retrieved from http://static.nsta.org/files/jcst1503_82.pdf

Smith, M. K., Jones, F. H., Gilbert, S. L., & Wieman, C. E. (2013). The classroom observation protocol for undergraduate STEM (COPUS): a new instrument to characterize university STEM classroom practices. *CBE life sciences education*, *12*(4), 618-27. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3846513/#!po=80.3030

Soneral, P. A., & Wyse, S. A. (2017). A SCALE-UP mock-up: Comparison of student learning gains in high- and low-tech active-learning environments. *CBE life sciences education, 16*(1):ar12.

Stains, M., Harshman, J., Barker, M., Chasteen, S., Cole, R., Dechenne-Peters, S., … Young, A. (2018). Anatomy of STEM teaching in North American universities. *Science (New York, N.Y.), 359*(6383), 1468–1470. Retrieved from https://doi.org/10.1126/science.aap8892

Stoltzfus, J., & Libarkin, J. (2016). Does the room matter? Active learning in traditional and enhanced lecture spaces. *CBE life sciences education, 15*(4). doi:10.1187/cbe.16-03-0126

Theobald, R., & Freeman, S. (2014). Is it the intervention or the students? Using linear regression to control for student characteristics in undergraduate STEM education research. *CBE Life Sciences Education, 13*(1), 41–48. Retrieved from https://doi.org/10.1187/cbe-13-07-0136

Udovic, D., Morris, D., Dickman, A., Postlethwait, J., & Wetherwax P. (2002). Workshop biology: Demonstrating the effectiveness of active learning in an introductory biology course. *BioScience, 52*(3), 272-281. Retrieved from https://doi.org/10.1641/0006-3568(2002)052[0272:WBDTEO]2.0.CO;2

Von Glasersfeld, E. (1989). Constructivism in education. In Husen, T. & Postlewaite, N. (Eds.), The International Encyclopedia of Education, Supplement (1). Oxford/New York: Pergamon Press, 162-163. Retrieved from http://www.vonglasersfeld.com/114

Vygotskiĭ, L. (1962). Thought and language. Cambridge: M.I.T. Press, Massachusetts Institute of Technology.

Vygotskiĭ, L., & Cole, M. (1978). Mind in society: The development of higher psychological processes. Cambridge: Harvard University Press.

Wolfe, E. J. (2008). Evaluating the use of the SCALE-UP teaching methodology for an undergraduate database systems course (Order No. MR41171). Available from ProQuest Dissertations & Theses Global. (230759981). Retrieved from https://ezproxy.lib.ndsu.nodak.edu/login?url=https://search.proquest.com/docview/230759981?accountid=6766

APPENDIX A. INTERVIEW QUESTIONS

1. Tell me a little bit about your teaching philosophy – both now and in the past

    a. How many years have you been intentional about using active learning pedagogies?
    b. How did you prepare yourself to start using active learning pedagogies?
    c. Did you receive any training or preparation for teaching in a SCALE-UP classroom?
    d. I understand the culture in the Biological Sciences department is very supportive of using active learning pedagogies.

        i. How, specifically, has this helped you in shifting your pedagogies?
        ii. If your department was not as supportive, do you think you would be using active learning pedagogies today?

2. Imagine I was a student in your Biol 151 class, attending a typical class session in an auditorium – walk me through what I would experience from start to finish.

    a. Why did you structure your courses in these ways?
    b. While teaching in the auditorium, how, if at all, did your active learning techniques evolve over time?

3. Now imagine I was a student in your Biol 151 class, attending a typical class session in the SCALE-UP room – walk me through what I would experience from start to finish.

    a. How do you use the structure of the classroom (whiteboards, round tables, student technology, and the instructor technology)?
    b. Did your use of constructivism and social constructivism practices evolve, in terms of quantity and quality, since you began teaching in the SCALE-UP classroom?
    c. Has there been a shift in your assessment practices over time?
        i. If so, reflect on how and why?
    d. After three years of teaching in the SCALE-UP classroom, do you feel your teaching practices are fully developed or do you feel they will continue to evolve as you gain more experience teaching in the SCALE-UP classroom?

4. How has the use of learning assistants evolved over time?

    a. The syllabi indicate having 6 LAs when you were in the auditorium, and 4 when you moved to SCALE-UP – then down to 3 for Spring 2018. However, the COPUS observation indicates you only had 3 LAs the entire time in SCALE-UP.
        i. Has the decrease in LAs had a negative impact?

        ii. Do you feel you have enough LAs in the classroom?
    b. When teaching in the auditorium, what types of things did the LAs do?
    c. When teaching in the SCALE-UP classroom, what types of things do the LAs do?
        i. Has the SCALE-UP LA work been evolving over the past 3 years?

5. You discussed the typical experience in the auditorium and the typical experience in the SCALE-UP classroom; could you now elaborate on the quality of the various active learning techniques you use in both environments?

    a. <If any of the techniques were used in both environments> … You mentioned that you use the <technique> in both the auditorium and the SCALE-UP classroom, how, if at all, is the quality of the exercise different?
    b. <If any of the techniques are new to SCALE-UP>….How, if at all, does the <new technique> facilitate deeper learning of the course content?

6. In the analysis of the syllabi, I noticed the following changes:

    a. For your first year in SU, you quit having the students use the textbook access code.
        i. For your second year in SU:
            1. The course content shifted
            2. Switched to a new textbook
            3. Clickers were no longer being used, replaced by carbonless notebooks.
        ii. For the third year in SU, the textbook was replaced by an OER book, and it appears you went down one LA.
        iii. Do you feel any of these changes would have an impact on the findings of the study?

7. In the analysis of the COPUS data, there was only 1observation done while you taught in the auditorium, and at least 4 observations are needed for the findings to be valid; therefore recognizing this flaw with the data, I analyzed the results qualitatively looking for trends over time.

    a. Using the COPUS instructor profile analysis used by Stains et al. (2018) as a framework, I categorize you as having a student-centered instructor profile, both in the auditorium and in the SCALE-UP classroom. Which is impressive, because Stains et al. only found 18% of the 548 instructor profiles analyzed to be student-centered.
    b. What I found between the auditorium and the SCALE-UP classrooms were relatively small shifts to the student and instructor behavior codes that were analyzed.

i. You lectured slightly more in the auditorium than in the SCALE-UP classrooms, but not a huge difference (Aud. 55% of the time, the SCALE-UP ranged from 30%-50%).
ii. Students asking questions has been fluctuating, but trending down (25% in aud, down to 10% in 2nd year, back up to 17% the 3rd year).
iii. The instructor posing questions to the students has been fluctuating, but seems to be trending down in the last two SU years (Aud 35%, SU AM 40%, then dropping to 20%)
iv. 1:1 work has been increasing over time, from 0% in the auditorium to 10% in the 3rd year.
v. Most surprising was student group work. The highest percentage of group work was actually done in the Auditorium, not a huge difference. (Aud 30%, SCALE-UP ranged between 15% - 25%).

c. Once again, with only 1 observation in the auditorium, the findings may not be representative of your teaching practices.
d. Would you reflect, and provide a deeper understanding of the COPUS findings?

8. Using multiple linear regression analysis, the SCALE-UP classroom was not found to be a significant predictor of an increased Biology 151 course grade once student characteristics, such as College GPA, HS GPA, and Biology 150 grade were controlled for, despite ANOVA results indicating that students grades *were* significantly higher in SCALE-UP, beginning with year 2 and carrying through year 3. Furthermore, the COPUS findings categorize your teaching profile as being student-centered, in both the auditorium, and in the SCALE-UP classroom.

   a. Considering these findings, collectively, can you share some insights on your experiences and expectations with regard to student success in Biology 151 classrooms?

APPENDIX B. IRB APPROVAL

NDSU NORTH DAKOTA STATE UNIVERSITY

February 25, 2019

Dr. Erika Beseler Thompson
School of Education

IRB Approval of Protocol #HE19174, "Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP): Effective Tool for Biology?"
Co-investigator(s) and research team: Melissa Stotz, Chris Ray, Angela Hodgson

Protocol Reviewed: 2/25/2019 Protocol update due: 2/24/2022

Research site(s): NDSU Funding Agency: n/a
Expedited Review Category: 5

IRB approval is based on the original protocol submission (rec'd 2/20/2019).

Additional approval from the IRB is required:
o Prior to implementation of any changes to the protocol (Protocol Amendment Request).

Other institutional approvals:
o Research projects may be subject to further institutional or departmental review and approval processes.

A report is required for:
o Any research-related injuries, adverse events, or other unanticipated problems involving risks to participants or others within 72 hours of known occurrence (Report of Unanticipated Problem or Serious Adverse Event Form).
o A Protocol Deviation Report is required for any departures from the approved protocol.
o Any significant new findings that may affect risks to participants.
o If the study will continue beyond the protocol update due date (Protocol Status Update).
o Closure of the project (Protocol Termination Form).

Research records are subject to random or directed audits at any time to verify compliance with human subjects protection regulations and NDSU policies.

Thank you for cooperating with NDSU IRB procedures, and best wishes for a successful study.

Sincerely,

Kristy Shirley

Kristy Shirley, CIP, Research Compliance Administrator

For more information regarding IRB Office submissions and guidelines, please consult www.ndsu.edu/irb. This Institution has an approved FederalWide Assurance with the Department of Health and Human Services: FWA00002439.

INSTITUTIONAL REVIEW BOARD
NDSU Dept 4000 | PO Box 6050 | Fargo ND 58108-6050 | 701.231.8995 | Fax 701.231.8098 | ndsu.edu/irb

Shipping address: Research 1, 1735 NDSU Research Park Drive, Fargo ND 58102

NDSU is an EO/AA university.

NDSU NORTH DAKOTA STATE UNIVERSITY

February 25, 2019

Dr. Erika Beseler-Thompson
School of Education

Re: IRB Determination of Exempt Human Subjects Research:
Protocol #HE19175, "Active Learning Strategies Used in an Auditorium and Scale-Up Classroom"

Co-investigator(s) and research team: Melissa Stotz
Date of Exempt Determination: 2/25/2019 Expiration Date: 2/24/2022
Study site(s): NDSU
Sponsor: n/a

The above referenced human subjects research project has been determined exempt (category #2(ii)) in accordance with federal regulations (Code of Federal Regulations, Title 45, Part 46, Protection of Human Subjects). This determination is based on the original protocol submission (received 2/20/2019).

Please also note the following:
• If you wish to continue the research after the expiration, submit a request for recertification several weeks prior to the expiration.
• The study must be conducted as described in the approved protocol. Changes to this protocol must be approved prior to initiating, unless the changes are necessary to eliminate an immediate hazard to subjects.
• Notify the IRB promptly of any adverse events, complaints, or unanticipated problems involving risks to subjects or others related to this project.
• Report any significant new findings that may affect the risks and benefits to the participants and the IRB.

Research records may be subject to a random or directed audit at any time to verify compliance with IRB standard operating procedures.

Thank you for your cooperation with NDSU IRB procedures. Best wishes for a successful study.
Sincerely,

Kristy Shirley

Kristy Shirley, CIP, Research Compliance Administrator

For more information regarding IRB Office submissions and guidelines, please consult http://www.ndsu.edu/research/integrity_compliance/irb/. This Institution has an approved FederalWide Assurance with the Department of Health and Human Services: FWA00002439.

INSTITUTIONAL REVIEW BOARD
NDSU Dept 4000 | PO Box 6050 | Fargo ND 58108-6050 | 701.231.8995 | Fax 701.231.8098 | ndsu.edu/irb

Shipping address: Research 1, 1735 NDSU Research Park Drive, Fargo ND 58102