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Effects of Real-World Experiences in Active Learning (R.E.A.L.) Applied in an Information Systems Data Communication and Networking Course

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THE EFFECTS OF REAL-WORLD EXPERIENCES IN ACTIVE LEARNING (R.E.A.L.) APPLIED IN AN INFORMATION SYSTEMS DATA COMMUNICATION AND NETWORKING COURSE

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Dedicated in loving memory of my parents, Mr. and Mrs. Frank (Inez Marie) Lucas, Sr.

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LIST OF ABBREVIATIONS

ABET	Accreditation Board for Engineering and Technology, Inc.
ASPECT	Assessing Student Perspective of Engagement in Class Tool
AVE	Average Variance Extracted
CFA	Confirmatory Factor Analysis
EFA	Exploratory Factor Analysis
HI	Health Informatics
IC	Instructor Contribution
IS	Information Systems
IT	Information Technology
LTR	Long-Term Retention
MANCOVA	Multivariate Analysis of Covariance
MLM	Multilevel Modeling
PCAST	President’s Council of Advisors on Science and Technology
PE	Personal Effort
R.E.A.L.	Real-World Experiences in Active Learning
SEM	Structural Equation Modeling
STEM	Science, Technology, Engineering, and Mathematics
STR	Short-Term Retention

TCP/IP	Transmission Control Protocol/Internet Protocol
TEALS	Technology Education and Literacy in Schools
VGW	Value of Group Work
VIF	Variance Inflation Factor

ABSTRACT

Rhonda Luvenia Lucas, Ph.D., University of South Alabama, May 2023. The Effects of Real-World Experiences in Active Learning (R.E.A.L.) Applied in an Information Systems Data Communication and Networking Course. Chair of Committee: Debra Chapman, Ph.D.

The purpose of this study was to determine if the use of Real-World Experiences in Active Learning (R.E.A.L.) impacted student learning outcomes in an undergraduate information systems (IS) data communication and networking course. A quasi-experimental, quantitative approach was used to investigate whether the R.E.A.L. treatments, used as active learning strategies, significantly impacted student performance, short-term retention, long-term retention, and student engagement.

The data collection was completed in one semester. Participants were students enrolled in an IS data communication and networking course during the Fall 2019 semester. The students, enrolled in the two sections of the course, were taught using a crossover design where each student received eight treatments. The researcher of the study served as the instructor for both sections. The research question and four hypotheses were analyzed using repeated measures MANCOVA and multi-level modeling (MLM).

After a statistical analysis of the direct effects of the R.E.A.L. treatments on student performance, short term retention, long term retention, and engagement, none of the four hypotheses were fully supported. The results indicated that the R.E.A.L.

treatments did not significantly impact the student learning outcomes from the course. Research findings partially supported hypothesis H1 indicating that age, ethnicity, and major have some influence on students' performance and age may have some influence on short-term retention. Statistically significant results were obtained for the H1a Network treatment $(F(1,28) = 6.033, p = 0.021, \text{partial } \eta 2 = 0.177)$, meaning that the mean for the H1a Network treatment $(M = 90.842)$ was significantly different than the lecture mean $(M = 75.533)$. The H1b Handshake treatment $(F(1,28) = 15.405, p = .001, \text{partial } \eta 2 = 0.355)$ and the H1c Wireless treatment $(F(1,28) = 11.385, p = .002, \text{partial } \eta 2 = 0.289)$ produced results in the reverse direction of what was hypothesized, meaning that the mean for the H1b Handshake treatment (M = 49.800) and the H1c Wireless treatment (M = 86.842) were significantly lower than the lecture means for both hypothesis tests. Research findings partially supported hypothesis H2 indicating that age may have influence on short-term retention. Statistically significant results were obtained for the H2e Network speed treatment $(F(1,28) = 5.709, p = 0.024, \text{partial } \eta 2 = 0.164)$ and H2f Network management treatment $(F(1,28) = 5.654, p = 0.024, \text{partial } \eta 2 = 0.163)$. However, findings from the MLM post hoc tests of direct, interaction, and indirect effects did show some areas for future work in certain demographics, especially gender and ethnicity. Findings of the study were not shown to be significant however, the post hoc testing revealed areas where future work could be beneficial.

CHAPTER I

INTRODUCTION

Using active learning techniques in the classroom can have a pronounced effect upon students' learning. Active learning is generally defined as any instructional technique that engages students, requires them to do meaningful activities, and then reflect on or think about the activity (Prince, 2004). Active learning has become an umbrella term that encompasses modes of instruction derived from constructivism and the teaching methods that shift the spotlight from the instructor to the student, actively engage the mind, and connect higher-order cognitive thinking in the classroom setting (Barkley, 2010; Brame, 2016). Students have been shown to prefer active learning strategies over traditional lectures (Bergdahl, Fors, et al., 2018; Bonwell & Eison, 1991; Borrego et al., 2018; Ensign & Woods, 2014; Freeman et al., 2014; Grissom et al., 2017; Haak et al., 2011; Theobald et al., 2020). Research studies measuring students' achievement reveal that many active learning strategies are comparable to traditional lectures in promoting mastery of content (Caprio & Micikas, 1997; P. A. Johnson, 2011; Kitchens et al., 2018; Revell & Wainwright, 2009). Active learning strategies have been found to be superior to lectures in promoting the development of students' cognitive skills (Cummings et al., 2015; Michel et al., 2009; Prince, 2004). Additionally, a significant number of individuals have learning styles that are best supported by educational methods other than lecturing (Bonwell & Eison, 1991; Felder & Silverman, 1988).

College students benefit from the use of broad educational methods grounded in research (Bergdahl, Fors, et al., 2018; Grissom et al., 2017). Improved learning and higher retention rates in Science, Technology, Engineering and Mathematics (STEM) disciplines often occur when students become active participants in their own learning (Bergdahl, Knutsson, & Fors, 2018; Freeman et al., 2014; Grissom et al., 2017; Theobald et al., 2020). The instructor's use of evidence-based scholarly teaching approaches to instruction necessitates that faculty become well-versed regarding active learning strategies which can improve both their teaching and student learning outcomes (Barkley, 2010; Borrego & Henderson, 2014; Furse & Ziegenfuss, 2020; Silberman, 1996).

There is a growing interest in using active learning strategies in the computing classroom. Industry, government, and accreditation agencies have all called for a broader more active approach to teaching for improvement in the training, teaching, and preparation of IS students for practice in the workplace (Freeman et al., 2014; MacKinnon et al., 2016). Several academic institutions have received criticism regarding their higher education curricula not preparing students for the "real world" (Benito & Singhal, 2019; Burke & Fedorek, 2017; Levine, 2005). However, lecture, the oldest method of instruction which has been around since medieval times, continues to be mode of choice among faculty delivering higher education instruction (Margolis et al., 2015; Stains et al., 2018; Stearns, 2017).

1.1 Statement of the Problem

The purpose of this study is to determine how undergraduate student learning outcomes in an IS data communication and networking course are impacted when an active learning intervention is included with the traditional classroom lecture. A quasi-experimental, quantitative approach was used to explore whether the performance, short-term retention (STR), long-term retention (LTR), and engagement of the students that receive the active learning approach significantly differed from the students who received only the traditional lecture instruction.

The Bureau of Labor Statistics reported that between 2020 and 2030 STEM jobs are expected to increase 1.4 times faster than non-STEM jobs (Coleman, 2022; U.S. Bureau of Labor Statistics, 2021). They also predicted that computer and information technology-related jobs requiring a bachelor's degree will grow 15% from 2021 to 2031, much faster than the average for all occupations (U.S. Bureau of Labor Statistics, 2021). The computing industry continues to have more positions available than qualified graduates to fill the positions due to increased demands in cloud computing, big data, and information security jobs (U.S. Bureau of Labor Statistics, 2021). This makes it vital for higher education to prepare students for these jobs (Beasley & Floyd, 2013; Dillon & Slattery, 2018; Keengwe et al., 2014).

The need for skilled technologists calls for a paradigm shift in how technology is taught (U.S. Bureau of Labor Statistics, 2018). The high attrition and low retention rates reported for undergraduate student enrollment in STEM majors result from a variety of factors, including the lack of adequate preparation for college by the student, the lack of student confidence, and the persistent use of traditional lecture (Freeman et al., 2014; Xu, 2016). Research has examined the problem of student performance concerning traditional lectures and supports improved results with active learning. Xu (2016) observed STEM students preferred active learning activities and research projects over traditional lectures. In addition, when undergraduate STEM student performance between traditional lecturing and active learning strategies was compared, students in traditional lecture courses were 1.5 times more likely to fail than those in classes that used active learning strategies and the average exam scores improved by approximately 6% in the active learning class sections (Freeman et al., 2014).

The increased use of active learning could “ameliorate the challenges caused by shortages of software developers and information technology specialists” (Eickholt, 2018, p. 1). Grissom et al. (2017) suggest that with only 31% of incoming students enrolled in a computer science related degree program actually graduating from that program, faculty should adopt more student-centered practices. The National Science Foundation grants funding to promote active learning in STEM to prevent shortages of STEM graduates (Douglas et al., 2017; National Science Foundation, 2020; Yuan & Cao, 2019). While there are many reasons for low retention and graduation rates, research shows that the rates could improve if college faculty shift from teacher-centered to more student-centered teaching practices, including active learning, inside the computer science classroom (Grissom et al., 2017; Wieman, 2014).

Faculty are under pressure to reach the undergraduate student of the 21st century. Many of today’s incoming college students are digital natives that have grown up with technology (Bennett et al., 2008; Prensky, 2001). These students are the first generation to grow up engrossed in technology that is readily available at their fingertips (Bennett et al., 2008). A number of digital natives used alternative educational activities and technology to aid in their learning during the elementary and secondary grade levels. They also experience more standardized exams than earlier generations; spend a large portion of their free time on social media (Facebook, Instagram, Snap Chat, TikTok, etc.); play video games; depend on their smart devices (phones, watches, tablets, etc.) for everything from making a phone call to instant messaging; inhabit virtual reality; stream movies, music, and TV continuously; create and read blogs and wikis; listen to podcasts; and depend on the Internet and World Wide Web for answers to day-to-day questions (Bennett et al., 2008). Yet, the traditional lecture method of teaching is still prevalent in the college classroom setting and can be a least desired approach to learning for these students (Grissom et al., 2017; Maycock, 2019; Spahr, 2017; Stearns, 2017; Wheatley, 2018). This presents opportunities and challenges to faculty seeking to engage the digital natives. Faculty may need to adapt or change their teaching techniques to reach the learning styles of this generation (Cote & Allahar, 2020; Ford et al., 2019).

There has been considerable research on active learning at the elementary and secondary grade levels that supports the benefits of active learning, including improved critical thinking skills, increased motivation to learn, cooperative learning, student engagement, and greater retention of knowledge, and revealed the importance of active learning strategies to improve achievement, increase conceptual understanding, and improve attitudes/motivation (Darling-Hammond et al., 2019; Michael, 2006; Ntuli, 2015; Tharayil et al., 2018). Additionally, research has addressed the effects of active learning strategies in some higher education computing courses, however, there is limited research on the use of active learning strategies in an undergraduate IS data communication and networking class. Liu (2006) used a backward course design approach to examine how active learning exercises can engage students more thoroughly to understand IS data communication and networking concepts in a university classroom setting. Backward design approaches start with setting goals, such as how students are to use knowledge after the course, before choosing instructional methods and forms of assessment (Handelsman et al., 2004). The backward design approach was determined to be a success in enhancing K-12 instruction and learning, and is now being implemented at the college level as seen in the Reynolds and Kerns (2017) study at Indiana University Bloomington.

1.2 Research Question

Active learning has been shown to be effective at improving the outcomes of traditional lecturing (Freeman et al., 2014). The R.E.A.L. treatments provided the students a chance to encounter problems and challenges from a real-world perspective. They were backward designed activities that allowed the students to perform practical networking skills in a classroom setting that reinforced concepts covered in the course and supported the student learning outcomes for the course. They were variations of examples presented in the course's textbook providing skill-based educational opportunities. The students in the study were exposed to two instructional methodologies: traditional lecture and lecture enhanced with active learning using R.E.A.L. treatments. The study's goal was to determine whether the implementation of R.E.A.L. treatments impact student performance, short-term retention, long-term retention, and student engagement in the course while improving student learning outcomes. With this goal, the general research question developed for this study was:

Do active learning strategies impact student learning outcomes in an undergraduate IS data communication and networking course?

While research has addressed the effects of active learning strategies in higher education computing courses, there are limited empirical studies examining the effects of active learning strategies in an IS data communication and networking classroom setting.

The remainder of this dissertation includes the following chapters. Chapter II presents a review of the relevant literature that has been researched in the study. The literature review focuses on previous research and fundamental concepts of the constructivism learning theory and its practical application of the teaching method, the need for a paradigm shift in higher education, the importance of active learning in higher education, computing, and in an IS data communication and networking course. Chapter III describes the research design. This includes the research participants of the study, the data collection procedures, and the statistical analysis procedures used to address the research question and hypotheses. Chapter IV includes a description of the findings from the data analysis. Chapter V discusses the implication and a summary of the findings, final conclusions, research limitations, and recommendations for practice and future research.

CHAPTER II

REVIEW OF RELATED LITERATURE

Chapter II addresses the literature concerning this study and includes: (1) theoretical framework of constructivism; (2) defining active learning strategies; (3) active learning in higher education; (4) active learning in STEM; (5) benefits of active learning; (6) barriers to active learning; (7) calls for active learning; and (8) summary.

2.1 Theoretical Framework of Constructivism

Constructivism is a learning theory founded on the belief that students actively construct their own knowledge based on one's experiences as a learner rather than receiving and storing knowledge communicated by the teacher through passive lectures (Ben-Ari, 2001). Constructivism involves learning that is "an active process in which meaning is developed on the basis of experience" (Bednar et al., 1992, p.21). The constructivist learning theory is grounded in scientific study and observations about how people learn. It is based on the premise that people construct a personalized knowledge of the world applying prior experiences and information (Bada & Olusegun, 2015; Cooperstein & Kocevar-Weidinger, 2004; Pritchard & Woollard, 2013).

Constructivism gave rise to active learning pedagogies (Bada & Olusegun, 2015; Ismail et al., 2020; Kamenetskiy, 2020). In the early 20th century, American students were taught using rote learning and authoritarian teaching (Handelsman, et al., 2007). John Dewey, an American philosopher and educational reformer, provided the philosophical model for modern constructivist theory by determining that students were not merely empty vessels to be filled with facts and concepts by teachers (Kivinen & Ristela, 2003). In his book, *Democracy and Education*, Dewey (1903) stated that each person creates and manages their own knowledge with prior knowledge being an important factor in one's learning process. Other important constructivist theorists include Lev Vygotsky, Jean Piaget, and Jerome Bruner.

Based on social constructivism, Vygotsky's theory focused on the child developing through social context and shared problem-solving (Bada & Olusegun, 2015; Liu & Matthews, 2005). Vygotsky developed the *zone of proximal development* where acquiring knowledge when working with a skilled partner, which can be either an instructor or peer, can lead to enhanced mental development (Bada & Olusegun, 2015; Liu & Matthews, 2005; Verenikina, 2003). He also stressed the importance of scaffolding (Bada & Olusegun, 2015; Liu & Matthews, 2005; Verenikina, 2003). Scaffolding is an instructional technique that breaks down a complex problem into smaller steps, examples, or prompts that, in turn, provide support to the students until the students can solve the problem or complete the task (Barkley, 2010) and includes critical listening, prompting, and direct feedback as approaches for instructors, peers, or coaches (Bada & Olusegun, 2015; Liu & Matthews, 2005; Verenikina, 2003). The *zone of proximal development* is frequently labeled as the theoretical foundation of scaffolding; however, both related teaching methods and their implementation vary depending on the researcher (Bada & Olusegun, 2015; Liu & Matthews, 2005; Verenikina, 2003).

Piaget's version of constructivism focused on people using interactions with their peers to make meaning of new knowledge based on their own experiences and ideas (Arman, 2018; Bada & Olusegun, 2015). His work examined cognitive constructivism, focusing on how the learner builds knowledge based on new and prior understanding of a topic (Bresler et al., 2001; Dung, 2019). Piaget's theory on child development contributed to constructivism by having teachers view students as learners who construct their understanding by adding new concepts to prior knowledge (Dung, 2019). The Piagetian model focus is on how the child interacts with their environment in the creation of new knowledge (Bresler et al., 2001; Dung, 2019).

Bruner's work encouraged the use of Socratic learning, where the instructor and the students participate in an active interchange of scaffolding learning within a social context allowing the students to interact with experts to increase learning effectiveness (Bada & Olusegun, 2015; Christie & De Graaff, 2017). His work in educational psychology sought to better understand the needs of students. Bruner (1961) wrote that knowing how to assemble an item was more effective learning than memorizing a thousand facts about the item. Bruner contributed to educational psychology and curriculum, developed a theory of cognitive growth, and promoted a range of important educational programs worldwide, including the early childcare program Head Start (Bresler et al., 2001; Bruner, 1961). He also advocated a complete spiral curriculum in which the same subject is taught at various levels starting with the basics and details added as the student advances grade levels allowing the learner to continually build on prior learning (Bresler et al., 2001; Bruner, 1961).

David Ausubel, an American psychologist and science education contributor, believed that the teacher's role was that of a facilitator or helper where they provide the scaffolds or framework to assist the student in organizing knowledge (Ausubel, 1963, 2012). He believed constructivism-based activities could be used as a tool to transform teaching where students acquire new knowledge by creating scaffolds that help them to better organize and retain fact and ideas (Ausubel, 1963, 2012). The role of the teacher in this process is modified, not eliminated, where the teacher becomes a facilitator. The teacher acts as an authority or leader and aids the students to construct their own knowledge through guided learning. The students are required to take personal responsibility for their learning process. The student must be engaged for the scaffold technique to be used and to accomplish the learning goal (Handelsman et al., 2007). The implementation of constructivist-based activities can transform the classroom from a teacher-centered to a learner-centered environment where the teaching focus is shifted from the teacher to the student (R. T. Johnson & Johnson, 2008).

Some critics of constructivism view it as a learning theory that forces students to *reinvent the wheel* or find a solution when one already exists (Bada & Olusegun, 2015; Meyers & Jones, 1993). In reality, however, constructivist-based activities have the student attempt to understand how the wheel operates, apply their prior knowledge and real-world experience, formulate questions on their own, hypothesize a solution, and ultimately figure out how the wheel works (Bada & Olusegun, 2015). Constructivism engages the student and makes them use their critical thinking skills to re-evaluate and construct their understanding and knowledge and not create something that already exists (Bada & Olusegun, 2015; Meyers & Jones, 1993).

Critics also believe that constructivism negatively reduces the role of the instructor who is the knowledge expert (Bada & Olusegun, 2015). While it is true that constructivism restructures the role of the instructor from being directive to being interactive and promotes real-world problem solving in a collaborative learning setting (Bada & Olusegun, 2015), the main role of the instructor remains vital in constructivist activities as a facilitator and a guide as the student acquires new knowledge.

Constructivist-based activities help to engage and motivate students by requiring them to take a more active role in their learning process and can easily be adapted to any discipline (Bada & Olusegun, 2015; Cooperstein & Kocevar-Weidinger, 2004). In a constructivist class setting, the instructor and students view knowledge as something that is always changing. A group discussion is one example of a constructivist class activity where the teacher asks a major question, divides the students into teams, and allows team members to collaborate, share ideas, negotiate to an answer, and receive feedback from the instructor (Dung, 2019). This is a constructivist activity because the students are doing more than simply listening to a lecture. The students are an active participant in their learning process, while the teacher acts as the facilitator providing feedback and scaffolding instructions when needed during the group discussion. Active learning strategies grew out of constructivist learning theories and need wider acceptance to lead to improved student performance in exam scores, greater comprehension, and increased student retention of course material in comparison to the traditional lecture (Freeman et al., 2014).

2.2 Defining Active Learning Strategies

Active learning strategies is an umbrella term that covers a wide range of educational methods that involves a student-centered approach (Armbruster et al., 2009; Gilboy et al., 2015; Kane, 2004; Linton et al., 2014) and lacks a specific universally accepted definition (Kane, 2004; Linton et al., 2014; Prince, 2004). In general, active learning can be defined as any teaching method that engages the students in the classroom where they are doing more than simply listening but are active participants in the learning environment, including reading, writing, discussing, or engaged in solving problems (Bonwell & Eison, 1991; Faust & Paulson, 1998; Prince, 2004). Prince (2004) agrees with the definition of active learning as a technique that demands that students engage in meaningful learning activities and reflect on their actions. Active learning stresses the importance of applying content to better comprehend the material and skills taught in a course (Auster & Wylie, 2006; Lundstrum, 2020). Active learning actively engages the mind and connects students in instructional activities that promote higher-order thinking (such as analysis, synthesis, and evaluation in Bloom's taxonomy) to involve students in doing things and thinking about the things they are doing (Bonwell & Eison, 1991).

The initial definition of active learning has expanded and evolved to include what is included, and not included, in active learning. Specifically, the traditional lecture approach where the student passively listens to an expert who provides information and instructions for conducting the activity using one-way communication, which does not engage the student, is not considered active learning (Bonwell & Eison, 1991). Fink (2003) reports how holistically the three components of active learning (information and ideas from primary and secondary data sources, rich learning experiences such as debates and authentic projects, and reflection through writing or discussion dialogue) are used to produce activities capable of creating significant learning. These meaningful learning activities can last for only a few minutes, an entire class meeting, or a full semester (Faust & Paulson, 1998; Furse & Ziegenfuss, 2020; Silberman, 1996).

Active learning involves students engaging in meaningful learning activities and thinking about the concepts they are learning (Bonwell & Eison, 1991; Freeman et al., 2014; Prince, 2004). Active learning can use in-class activities and instruction to accompany the traditional lecture method (Faust & Paulson, 1998). Research shows that active learning strategies incorporated with lectures can vary in complexity during a single class session (Faust & Paulson, 1998; Furse & Ziegenfuss, 2020; Silberman, 1996). A plethora of active learning strategy activities, including guided note taking, one minute papers, active debate, crossword puzzles, and concept maps, can be applied in the classroom setting to increase students' participation and enrich student learning (Eickholt, 2018; Laudien & López-Fitzsimmons, 2020; Michael, 2007; Reid, 2014; Silberman, 1996; Tuya & Indra, 2017). Appendix A describes a brief list of active learning strategies (Bonwell & Eison, 1991; Eison, 2010; Faust & Paulson, 1998; Furse & Ziegenfuss, 2020; Mitchell et al., 2017; Silberman, 1996).

Active learning is not a novel instructional approach. It is a philosophy and a movement that has been around since at least 400 BC. Socrates used the *thought content to change thought* processes approach, which focused on students using pre-existing knowledge. He also encouraged his students to actively take part in a learning dialogue where the teacher/facilitator asked the students questions and allowed them to think through the questions in an effort to stimulate critical thinking (Overholser, 1992). In 1924, John Dewey became a champion for active learning in the classroom by encouraging students to be involved in learning activities that engaged both their hands and minds (Meyers & Jones, 1993). He also encouraged minutes of silence for reflection in the middle of lectures so that a concept can develop (Dewey, 1910).

R. W. Revans (1982, 2017) introduced the concept of *action learning*, which involves empowering people to learn with and from each other, by providing a feedback loop of programmed instruction and questioning that entails a problem-solving approach of taking action and reflecting upon the results. Revans (1982) stated that learning should involve the student doing something and established the tone for what is now known as active learning. In the 1990s, Bonwell and Eison's (1991) active learning continuum helped to popularize the term active learning in education. The continuum is a conceptual framework showing that active learning can move from simple short and unstructured tasks to more complex longer duration planned and structured tasks (Bonwell & Eison, 1991). Their research focused on the importance of active learning in higher education to eliminate the gap between teaching using lecture-only versus teaching that includes using research-based teaching methods like active learning strategies and presented empirical results supporting the use of active learning.

The empirical results presented in the Bonwell and Eison (1991) executive summary included research on the modified lecture that demonstrated a low risk pausing approach where the instructor paused for two minutes three times during the lectures for students to work in pairs to discuss and rewrite their notes (Ruhl et al., 1987). At the end of the lecture, students reflected for three minutes on what they remembered, while the control group received the same lecture minus the pauses for reflection. Students that had the lectures with the incorporated pauses performed up to two letter grades better on the comprehensive exam. According to Milton and Eison (1983), brief tests and quizzes have an impact on what students learn, how they learn it, and how much they study. While Menges and Rando's (1989) research showed that students recalled nearly twice as much knowledge when given quick assessments and quizzes after lectures. After studying alternative lecture formats, Osterman (1984) developed the feedback lecture. The feedback lecture consisted of a supplemental study guide that included reading assignments, pre- and post-tests, learning objectives, and a summary of lecture notes. The feedback lecture follows a basic structure consisting of two mini lectures and a small group study session. Eighty-eight percent of the participating students favored a course using the feedback lecture, 99% gave the method a favorable rating.

Kelly and Holmes (1979) developed the guided lecture where the students were told lecture objectives, instructed to put their pencils down, listen intently to the presentation, extract and remember the key ideas, and then given five minutes to write down the information they remembered. They were then divided into smaller discussion groups to recount the lecture. When a student's reflection is unclear, the instructor clarifies it. Later that day, students are encouraged to reflect on and write what they remembered from the guided lecture in narrative form without referring to their notes. Fraas (1982) reported that students who responded favorably to simulation techniques (as identified by the learning style questionnaire) performed better in the experimental classes than their counterparts in the control classes, whereas students who responded favorably to lecture/discussion methods performed better in the experimental classes than their counterparts in the control classes. By providing feedback on the course material, the “responsive lecture” was developed as an addition to resource-based learning modules to meet the needs of individual students (Cowan, 1984). During one class period each week, open-ended, student-generated questions on any subject were answered, with limitations. Questions were required on every topic. Everyone had the option of asking a question, but they had to provide a brief rationale for why they believed it was important. After the students arranged the questions based on general interest, the instructor taught as many themes as time allowed.

Additionally, examples presented at the conference on how to implement active learning techniques including classroom discussion, visual learning, writing in class, cooperative learning, case studies, guided design, computer-based learning, debates, drama, role-playing, simulations, games, and peer teaching (Bonwell & Eison, 1991). They published empirical research on active learning, presented a framework for educators to use to implement active learning, and to make the teaching methodology a part of their present-day instructional approach. Their research, in combination with Prince’s (2004) research supported this researchers’ working definition of active learning, which entails students doing things and reasoning about the things they are doing (Bonwell & Eison, 1991; Eison, 2010) and involves them to complete meaningful learning activities.

2.3 Active Learning in Higher Education

Research postulates that applying active learning techniques in the higher education classroom can develop students’ autonomy (Sparrow et al., 2020). The Chinese

Proverb, “Give a man a fish and you feed him for a day. Teach a man to fish and you feed him for a lifetime” (Herzberg & Herzberg, 2012) credited to Lao Tzu, Chinese philosopher and writer, is still relevant. The proverb can be related to teaching by noting it is better to teach students how to think, analyze, strategize, and solve the problem themselves than to simply give them the answer. If you teach students skills, like how to think analytically, they will always have that skill.

Research suggests that students learn more when they are engaged in active learning because more emphasis is placed on the higher order thinking skills of evaluation, synthesis, and analysis (Bonwell & Eison, 1991; Freeman et al., 2014; Kressler & Kressler, 2020). Students may also prefer active learning strategies to traditional lectures due to the student-centered, collaborative, multimodal activities (Bonwell & Eison, 1991; Ensign & Woods, 2014; Freeman et al., 2014; Haak et al., 2011; Sibona et al., 2018). Educational systems worldwide are continuously changing with the goal of enabling students to develop and learn how to learn (Theobald et al., 2020).

Quantitative and anecdotal support exists for the effectiveness of incorporating active learning techniques in higher education classrooms and lessons. Bain (2011) describes the *best* college teachers as those who create learning environments where students solve real problems and students participate openly using active learning strategies which is the main tenet of active learning. In higher education, although students are accustomed to lecture, they often desire more (Auster & Wylie, 2006). Students want the instruction to also be engaging and interactive (Braxton et al., 2000; Chickering & Gamson, 1987; Strage, 2008). Braxton et al. (2000) found that college students who regularly participated in active learning activities in their courses felt that they gained more understanding and knowledge on the topic than if the same information was presented through only a traditional lecture. Students also felt that their overall collegiate experience was improved and more rewarding when it included active learning (Braxton et al., 2000). A shift from teacher-centered to student-centered teaching in the higher education classroom requires the student to take ownership of and be involved in their learning (Bonwell & Eison, 1991; Lumpkin et al., 2015). Students will need to use higher levels of thinking (Anderson & Krathwohl, 2001) and no longer be simply spectators in their education. They must talk, write, relate, and apply what they are learning in their daily experiences (Chickering & Gamson, 1987).

2.3.1 The Traditional Lecture

The majority of college faculty still use the traditional lecture (Keengwe et al., 2014; U.S. Bureau of Labor Statistics, 2018), which began in Western Europe and have been in use for over 900 years (Ruegg, 2004). The *sage on the stage* is the standard teaching method where the instructor imparts knowledge by lecturing to the class. In this traditional lecture approach, the student is a passive learner (Chua & Dziallas, 2012; King, 1993). Passive learning happens when the knowledge is transferred to the students themselves and the students are filled passively with knowledge given the answers to memorize and restate on an exam instead of actively participating in the learning process (Misseyanni et al., 2017; Ryan & Martens, 1989). In this one size fits all approach, the students receive, respond, and regurgitate the knowledge and do not directly participate in the learning process. Instead, the instructor is the central actor transferring the knowledge, and the student is the audience receiving the knowledge (King, 1993). Teaching techniques such as passive lectures continue to be the mainstay instructional mode in higher education (Hartley & Marshall, 1974; Schmidt et al., 2015; Stains et al., 2018; Stearns, 2017).

Philosophers including Dewey, Vygotsky, Piaget, and Bruner began challenging the lecture teaching style in the early 1900's by promoting a constructivist teaching approach (Bada & Olusegun, 2015; Bonwell & Eison, 1991; Liu & Matthews, 2005). Traditional lectures are still valuable and are the dominant mode of delivery (Hartley & Marshall, 1974; Schmidt et al., 2015). Lectures are a good way to transfer facts but may not be the best method to promote discussion, deeper thought, and higher level learning (Bligh, 1998). It should not be the only approach of instruction to help students master foundational concepts (Eison, 2010; Hamilton, 2013, 2018). College instructors need to design lectures to allow the student to achieve the higher Bloom's levels of learning taxonomy in analysis, synthesis, and evaluation (Anderson & Krathwohl, 2001; Hamilton, 2012, 2013, 2018). In current times, something is needed to supplement the lecture-only format (Bonwell, 1996; Bonwell & Eison, 1991; Connolly & Lampe, 2016; Prensky, 2001).

Lecture does not provide an in-class mechanism to ensure that students understand the concepts being covered (Hamilton, 2012, 2013, 2018). While the instructor may ask ad-hoc questions to encourage student participation (Hamilton, 2012; Prince, 2004), this method usually engages just a few students and does not provide specific feedback for the entire class (Prince, 2004). Students may learn definitions and key components from a lecture but may not be able to apply them or visualize an outcome (Prince, 2004). Modifications to the traditional lecture method are needed that can engage the student, increase student performance, and improve student outcomes (Koh et al., 2018; Meyers & Jones, 1993; Michel et al., 2009). There is a growing trend in higher education shifting toward using active learning techniques to augment traditional lectures (Campbell & Blair, 2018; Hamilton, 2018).

Research suggests that college faculty should do more than lecture because lectures limit the students' learning to the lower levels of Bloom's taxonomy of remembering and understanding (Anderson & Krathwohl, 2001; Forehand, 2010). The lecture-only paradigm encourages memorization and rote/surface learning as opposed to learning by doing, experience, or action which encourages deep learning (Bonwell, 1996; Meyers & Jones, 1993; Prince, 2004).

2.3.2 Transition to Active Learning Research

Active learning strategies, such as the cooperative learning activities think pair and share where instructors pose a question, the student thinks, and discuss their response with their classroom partner; exit quizzes given at the end of the lecture to measure what the student retains; jigsaw group activity in which group members become experts on a topic and create a group response; and case studies where students read a pre-defined scenario and the students reflect and formulate a response to a list of questions that accompany in-class lectures, have been used in the K-12 classroom settings for years (Elliott et al., 2017; Michael, 2006; Ntuli, 2015). Various higher education disciplines have seen positive effects of active learning including increased educational achievement, improved social benefits for students through collaborative and cooperative learning, and psychological advantages including the ability to interact with classmates (Faust &

Paulson, 1998). Active learning is gaining acceptance in many higher education disciplines including physics, science, engineering, and math (Felder & Brent, 2009; Freeman et al., 2014; Hernández-de-Menéndez et al., 2019; Lima et al., 2017; Theobald et al., 2020).

Today's students, as digital natives are different from previous students (Hamilton, 2012, 2013, 2018). Students have access to more resources (cell phones, laptops, etc.) in the classroom than in previous generations (Ambrose et al., 2010; Hamilton, 2012). The classroom landscape has changed (Abrahams, 2010) and students learn differently using technology (Abrahams, 2010; Bayraktar, 2001; Christmann & Badgett, 1999). Some active learning strategies involve using technology which may introduce challenges such as the lack of instructor training (Ambrose et al., 2010; Groff & Mouza, 2008; Ntuli, 2015; Stein et al., 2020), instructor inexperience with technology that is constantly changing (Groff & Mouza, 2008; National Research Council, 2000; Stein et al., 2020), the instructor lack of hardware and software (Groff & Mouza, 2008; National Research Council, 2000), and the lack of technical support for hardware and software (Groff & Mouza, 2008; National Research Council, 2000; Stein et al., 2020).

2.4 Active Learning in STEM

Active learning has been shown to be an effective teaching method in many of the STEM disciplines, including computing (Fisher et al., 2016; Mitchell et al., 2017). Research has consistently shown greater student achievement and engagement associated with active learning instructional methods in the STEM fields (Freeman et al., 2014). The Freeman et al. (2014) meta-analysis report identifies 225 studies comparing traditional lecture to active learning in university science, math, and engineering courses. The report helped to empirically validate active learning in STEM courses by demonstrating increases in examination performance of one half of a letter grade on average and decreased failure rates, between 21% - 32%, for active learning, well below the 55% seen with the traditional lecture. Freeman et al. (2007) used daily active learning sessions using clickers in an introductory biology course and achievement increased, most notably for high risk of failing students. Haak et al. (2011) reported that a college-level introductory biology class benefitted with improved performance by all students and a reduction in the achievement gap between disadvantaged and non-disadvantaged students when daily and weekly practice with problem-solving, data analysis, and other higher-order cognitive skills was implemented. Herreid and Schiller (2013) described a flipped course redesign that can be used to promote student thinking in and out of the classroom. Ruddick (2012) used videos to engage and focus student learning, case study, and active, student-centered methods to solve real-world problems using the flipped classroom. The results showed that the flipped classroom students performed better than the traditional lecture students as seen by their higher final exam scores (Ruddick, 2012). Dufresne et al. (1996) reported that students believed they learned more during their physics class by using the Classtalk tool that promoted active learning and enhanced communication within the classroom. Hoellwarth and Moelter’s (2011) research supported active learning in improving student performance in physics by showing that the structure of the course from the traditional lecture to the use of a studio format that involved computer based activities and small group work improved the students’ conceptual understanding and promoted learning gains for the students. Ogden et al. (2015) findings showed that active learning improved students' perceptions, mediated the effects of math anxiety and low self-efficacy, and increased students' motivation towards college algebra through a flipped teaching model which used innovative active learning instructional techniques during class. Felder and Brent (2015) research described the use of active learning in a chemical engineering course where instructor notes were turned into handouts with gaps for the students to fill in during the lecture resulting in improved exam grades, course grades, and scores on conceptual questions.

2.4.1 Active Learning in IS Education

The role of the IS educator is challenging. First, IS educators are faced with a constantly evolving, growing, and changing core curriculum as technology and computing continue to change (Murray et al., 2018; Oudshoorn et al., 2018). Additionally, the expectations placed on IS educators by professional organizations, accreditation boards, and industry change frequently (Bell et al., 2013). According to Moore's law (Moore, 1965), major technology changes occur anywhere from every twenty-four hours to eighteen months. Therefore, IS educators must constantly update their instructional material to keep up with the technological changes. Secondly, IS educators are challenged to use instructional strategies that not only increase academic achievement, but also encourages student engagement in the learning process and prepares students to apply the knowledge learned in the classroom to real-world experiences (Choi & Lee, 2009; Kaufman & Ireland, 2016). The IS instructor must not only be a content expert in their constantly changing subject area, but also have expertise in pedagogical training (Pratt et al., 2014).

Although the literature search did not identify specific research on the use of active learning strategies in an IS data communication and networking course, there is research focused on active learning in various other IS fields. McAvoy and Sammon (2005) demonstrated the usefulness of active learning when used in teaching agile methodology to instructors in a critical adoption factors workshop. Active learning was shown to be the preferred teaching approach in project management courses (McAvoy & Sammon, 2005; Schmitz, 2018; Sibona et al., 2018; Sibona & Pourreza, 2018). Additionally, when teaching agile methods in a health informatics course, role-playing learning activities were preferred over the traditional lecture method (Schmitz, 2018). Students learning Scrum in senior level IS analysis courses and in the introduction to management information systems courses preferred when an active learning exercise followed the lecture or when active learning was used alone (Sibona & Pourreza, 2018). Additionally, students' perception of the topic of Scrum project management was improved when active learning strategies were involved in senior level IS analysis classes and introduction to management information systems classes (Sibona et al., 2018).

In a system analysis and design course, research revealed that students might prefer active learning as the primary teaching method when case studies and real-world projects are used during class (Mitri & Cole, 2007; Reinicke & Janicki, 2010; Wong, 2017). Mitri & Cole (2007) indicated that students found group role-plays to be a good break from the traditional lecture. This active learning style of teaching required significant additional effort by the group and resulted in increased overall grade weight for the role-play case study assignment because of the increased communication, analytical, and decision-making skills required (Mitri & Cole, 2007). Additionally, Reinicke and Janicki (2010) used an active learning real-world two-semester project that combined system analysis and design with their capstone course. The active learning component was reported to be preferred by the students and resulted in improved student motivation to complete higher quality products because they had an actual customer. The inclusion of the active learning project improved and increased the group work by requiring more collaboration among the student teams, created more production-ready solutions, and allowed the students to be empowered to build their software solutions. Wong's (2017) results indicated that the hybrid approach to teaching a system analysis and design course, using a mix of traditional in-person sessions that focused on entrepreneurial-inspired projects and online learning modules on theory and concepts, worked well and created excitement provided that an instructor with industry experience taught the course.

Researchers reported that active learning was preferred when business scenarios, group discussions, and Wireshark were used in IS ethics courses (Niederman et al., 2011; Woods & Howard, 2014). Niederman et al. (2011) demonstrated that an active learning approach using the scenario technique to stimulate thinking gave students a powerful decision-making tool that allowed them to compare and contrast their different viewpoints. The researchers recommended using classroom exercises paired with a classroom discussion following the review and evaluation of business scenarios regarding the ethical use of information and IS (Niederman et al., 2011). Additionally, Woods & Howard (2014) found that active learning might be the preferred teaching approach in an IT ethics course that included a network sniffing activity using Wireshark and Linux. The activity engaged the students by making them think more about security on the web, think critically about their Internet usage, and how to protect themselves online. This study is probably the closest example of an active learning strategy related to an IS data communication and networking course.

Active learning was also a preferred through the use of group discussions and group activities in IT strategy research (Woods, 2016; Woods & Howard, 2015). Woods (2016) reported that students in an introductory IT course found the use of group discussions on current technology developments and the group activity to evaluate and develop a rubric enjoyable and would like this same type of learning repeated in future courses. Eighty percent of the students reported that the active learning activities improved their understanding of what technology professionals do. Most (70%) of the students enjoyed the activities and the majority (90%) would like to do them again.

Research on database curricula incorporated active learning methodologies through the use of real customer projects and MS Adventure Works software (Mitri, 2015; Podeschi, 2016). Podeschi (2016) integrated authentic projects into a database class where students had real customers, real risks, and real rewards. The results provided support for the active learning experience project which created an opportunity for collaboration and competition among the student teams allowing them to use both their technical and soft skills (Podeschi, 2016). Additionally, Mitri (2015) research used MS Adventure Works as an active learning teaching tool to gain a real-world understanding of the data model of a realistic business case. Survey results indicated that the students appreciated the effectiveness of Adventure Works in a classroom environment.

Students preferred the use of in-class demonstrations, in-class programming activities, and screencasts as the active learning preferred teaching mode in identified programming course research (Benander & Benander, 2008; Breimer et al., 2016; Kempner, 2015; Powell, 2015; Zhang et al., 2013). Benander and Benander (2008) employed an active learning exercise using the Towers of Hanoi demonstration to teach the students about recursion. The results revealed that the demonstration was perceived as an effective learning tool that helped the students develop a better understanding of the abstract concept of recursion and created more interest in programming recursive programming solutions (Benander & Benander, 2008). Additionally, Breimer et al. (2016) report that in-class active learning exercises in an introduction to Java programming course improved student satisfaction and increased programming practice time. However, the exercises did not improve student performance (Breimer et al., 2016). Kempner (2015) also integrated active learning steganography and cryptology examples into introductory programming courses. The students provided positive feedback which highlighted the value of team collaboration, problem-solving through reviewing classmates' programs for logic flaws, engagement with fellow students, and heightened interest in the fundamental principles of programming (Kempner, 2015). Powell (2015) reported that students who created screencasts while following along as the directions are given by the instructor and then working autonomously to create future screencasts scored significantly better on assessments and the final exam than those who did not. Zhang et al. (2013) results indicated that students in an introductory C programming course implementing an active learning environment had a statistically significant increased score in the programming competency for the experiential section than in a traditional lecture setting.

Computer science research reveals that students may prefer active learning (Anderson et al., 2007; Gao & Hargis, 2010; McConnell, 1996; Porter et al., 2013). McConnell's (1996) results from a general computer science and a theory of computation course showed students in the courses that implemented active learning activities, such as modified lectures, in-class groupwork to trace the execution of an algorithm, use of demo software to predict software solution outcomes, and the use role playing network protocols and abstract computer science concepts, performed better on the final exam than those exposed to lecture-only. Porter et al.'s (2013) longitudinal study on architecture, theory, and computer programming courses revealing that implementing active learning peer instruction methodology, an instructional method that replaces part of the traditional lecture with a small group activity often using clicker devices to capture student feedback, lowered failure rates by 67% in comparison to standard lecture instruction. Gao and Harris (2010) tested active learning using flip camcorders along with the lecture to promote an innovative educational approach in an introduction to computer science course. Results found the students were more engaged, more involved, and more creative than those exposed to traditional lecture-only. Additionally, Anderson et al. (2007) showed the use of active learning in a senior level algorithms course can support course-specific and instructor-specific classroom innovations and provide the students concrete examples in class to promote discovery and reinforce ideas by introducing a classroom tablet pc interactive system as a supplement to the traditional lecture. Although studies have examined active learning in STEM and specifically in computing fields, there is limited published investigative research in the field of IS as it relates to an introduction to IS data communication and networking course.

2.5 Benefits of Active Learning

Empirical research on active learning provides several benefits of using active learning strategies as a supplement to conventional lectures alone. Research shows that active learning approaches can positively affect student learning outcomes (Koh et al., 2018; Meyers & Jones, 1993; Michel et al., 2009). Benefits of active learning include: fostering higher order analytical and critical thinking skills (Michael, 2007; Prince, 2004; Woods et al., 2000), promoting cooperative learning where students collaborate to help each student to learn more (Luo et al., 2016; Prince 2004), student engagement through participating in class discussions (Faust & Paulson, 1998; Freeman et al., 2014; Prince 2004) increased retention of material (Faust & Paulson, 1998; Freeman et al., 2014; Michael, 2007; Prince, 2004; Ruhl et al., 1987; Xu, 2016), better attitude among the students toward the course material (Armbruster et al., 2009), and an increase in student performance (Faust & Paulson, 1998; Freeman et al., 2014).

2.6 Barriers to Active Learning

Although a large body of research and empirical data exists supporting active learning's positive effect on student learning outcomes, historically there has been resistance to the use of active learning techniques, from both instructors and students (Faust & Paulson, 1998; Michael, 2007; Stains et al., 2018). Significant barriers preventing the use of active learning strategies by faculty include: (a) higher education promotion and tenure processes are based on research and publications, not teaching and classroom instruction, (b) teaching methods are not traditionally included in most doctoral programs creating a gap of pedagogical knowledge for higher education instructors, (c) there is an absence of funding to purchase equipment including round tables, movable chairs, and large whiteboards that is needed to create learning spaces that support active learning, (d) faculty have a shortage of time to create and prepare new active learning activities (e) many faculty report apprehension regarding the ability to cover all of the discipline-specific material identified on the syllabus when using the more time-consuming active learning, (f) faculty feel like they have less effective classroom management and control when they are in the role of facilitator, (g) there is a strong influence of the historical and popular lecture tradition, and lastly, (h) a concern regarding student resistance to in-class activities that might lead to resentment, students not participating in the in-class activity, and possibly resulting in poor course evaluations at the end of the semester (Bourrie et al., 2014; Drake & Battaglia, 2014; Eickholt et al., 2019; Michael, 2007; Park & Choi, 2014; Reid, 2014; Tharayil et al., 2018). Identifying and understanding these barriers may be the first steps for faculty to encourage a pedagogical change. The use of active learning strategies can be stimulating for both faculty and students despite the potential barriers presented (Tharayil et al., 2018). Despite the reported benefits of active learning, actual adoption of active learning strategies remains minimal (Freeman et al., 2014).

2.7 Calls for Active Learning

Calls for incorporating active-learning instruction in undergraduate STEM courses have become increasingly strong as evidence continues to accumulate that active learning can be more effective than traditional lecture alone (Murray et al., 2018; President's Council of Advisors on Science and Technology (PCAST, 2012)).

Philanthropic organizations, government, and accreditation agencies have all called for a broader more active approach toward teaching in an effort to improve the training, teaching, and preparation of IS students for practice in the workplace (Freeman et al., 2014; MacKinnon et al., 2016). This change in undergraduate education is seen as necessary in order to improve student learning and to increase graduation rates (Borrego et al., 2010; Handelsman et al., 2004).

The Bill and Melinda Gates Foundation, a nonprofit private philanthropy established in 1999, focuses on education, global health, and library advocacy (Leknes, 2012). One of the foundation's missions is to transform the current model of higher education by advocating a "flipped" classroom approach where class time involves interactive activities, promotes constructivist learning theory, and promotes course redesigns that include active learning (Leknes, 2012; Young, 2012). To support their commitment to education, the Gates Foundation has awarded major grants focused on efforts to positively impact student outcomes, primarily in student learning, high school completion, and college attendance (Leknes, 2012; Young, 2012).

Microsoft Philanthropies established the Technology Education and Literacy in Schools (TEALS) program to connect high school teachers with technology industry volunteers to assist teachers in creating high school computer science programs in the United States and Canada (Ibe et al., 2018). TEALS is a national computer science education program that provides curriculum materials, volunteer training, professional development, and special events to promote active learning and formative assessment (Granor et al., 2016). The Gates Foundation and The Microsoft Philanthropies advocate for CS education reform.

Government agencies have also made an appeal for STEM education reform to increase the number of students who receive undergraduate degrees in STEM. The PCAST (2012) reports that the transformation is critical to increase the STEM graduation rate by 34% annually as needed to meet the goal of one million additional college graduates in STEM over the next decade. PCAST also recommended educators enlist classroom approaches that engage students in active learning. The council found a large body of empirical research that shows alternate instructional models can more effectively achieve many key learning outcomes than current practice (PCAST, 2012). Active learning techniques help all students by also helping to close the achievement gap seen in ethnicity and gender groups (Olson & Riordan, 2012).

The 2018 U.S. federal government's five-year strategic plan for STEM education report includes an objective to "Leverage and Scale Evidence-Based Practices Across STEM Communities" (Committee on STEM Education, 2018, p. 28) which incorporates critical thinking, problem solving, and higher order thinking skills. According to the research, STEM experiences that encourage students to be more active and engaged tend to help the pupils retain knowledge and develop critical thinking skills (Committee on STEM Education, 2018).

Accreditation organizations have also called for active learning in the classroom. IS educators often need to satisfy the criteria for accreditation boards, such as Accreditation Board of Engineering and Technology (ABET; Lending et al., 2019; MacKinnon et al., 2016). Accreditation adds value to technical academic programs through regular and effective assessment assuring the confidence that accredited academic programs meet their standards, including the need for teaching dynamic hands-on learning experiences to keep up with the rapid change of industry (ABET, 2017). Practical hands-on skills are critical but missing for many IS graduates (ABET, 2017). The 2017 ABET Impact Report describes a requisite for a transformation in education to move towards IS education based on dynamic hands-on learning, which occurs through the implementation of active learning strategies in the IS classroom (Murray et al., 2018; Oudshoorn et al., 2018). The goal of educators is to implement multiple modes of instruction, not just passive lecture, to achieve learning goals of the higher education accreditation bodies (Olson & Riordan, 2012).

Governments on the federal, state, and local levels have all begun to make STEM education a high priority (Blackley & Howell, 2015; Bybee, 2010; Thibaut et al., 2018). However, regardless of persistent calls from government for STEM education reform (Handelsman & Brown, 2016; Olson & Riordan, 2012), active learning strategies are still not prevalent in higher education (Bligh, 1998; Schmidt et al., 2015).

2.8 Summary

The present study focuses on the effects of R.E.A.L. active learning strategies in an IS data communication and networking undergraduate course. The use of active learning strategies has been shown to provide many benefits for students and instructors. Research reveals that some of the benefits of active learning strategies include improved student performance through the use of critical thinking skills (Breimer et al., 2016), increased retention (Faust & Paulson, 1998; Giannakos et al., 2017), and better or more student engagement (Faust & Paulson, 1998). Although lecture has been, and still is, the main style of instruction used in higher education (Brockliss, 1996), instructors can achieve many of the benefits by including active learning strategies to accompany the traditional lecture (Faust & Paulson, 1998).

Research on the effectiveness of specific active learning application exercises in an IS data communication and networking course is limited. Active learning has been integrated into STEM courses using various methods, with some evidence documenting improved students' performance when student-centered learning activities are used in the classroom to ignite student engagement (Freeman et al., 2014). Due to the lack of studies investigating the effects of active learning in an IS focused data communication and networking course, the results of this research will contribute to that body of knowledge. IS data communication and networking courses have traditionally used lecture-based instruction (Kuzlu, 2020). This research aims to quantify the effects of active learning in an undergraduate IS data communication and networking course in a university class setting on students' performance, STR, LTR, and student engagement.

CHAPTER III

METHODOLOGY

Chapter III outlines the research methodology used in this study and includes in detail: (1) hypotheses and model; (2) research design; (3) R.E.A.L. treatments; (4) description of course; (5) description of participants; (6) description of researcher; (7) measurement and variables; (8) pilot study; (9) data collection; and (10) summary.

3.1 Hypotheses and Model

The hypotheses for this study postulated the effects of the treatments on student performance, STR, LTR, and student engagement in the IS data communication and networking course. The relationships between the variables were modeled as presented in Figure 1. It was hypothesized that the students that received the R.E.A.L treatments would report improved performance, STR, LTR, and student engagement over those exposed to traditional lecture treatment.

As computing education continues to progress, educators are continually exploring innovative teaching strategies, like active learning strategies, to improve student learning outcomes. The aim of this study is to investigate the impact of active learning strategies on student performance. Student performance is used as a dependent variable to evaluate the effectiveness of the strategies used in this study. Loras et al.

(2021) conducted a systematic literature review aimed to determine what we know about the computing students study behaviors and how educational design influence their study habits. The analysis found that most of the papers that were chosen used various study behavior components to explain performance. Student performance, which is often measured through assessments, is a common indicator of student learning. Student performance was also measured in the Freeman et al. (2014) study. This hypothesis is based on the premise that active learning can improve student performance. The study was designed to investigate the following hypotheses and sub-hypotheses.

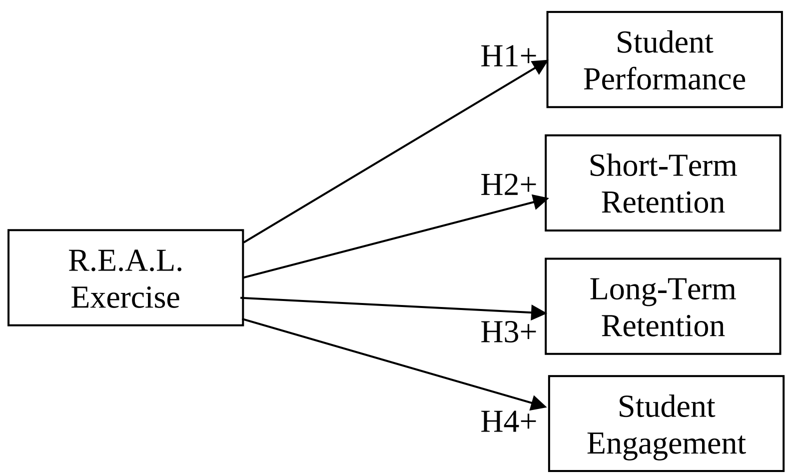

Figure 1. Model of Effects of R.E.A.L. Treatments.

It is with the understanding of these two studies we offer the following hypothesis:

H1: Students receiving a treatment with a lecture that incorporates a R.E.A.L. exercise will exhibit an increase in student performance over students receiving a traditional lecture treatment. H1a – H1h are the sub-hypotheses representing the eight treatments.

H1a: Students receiving a treatment with a lecture that incorporates the network R.E.A.L. exercise will exhibit an increase in student performance over students receiving a traditional lecture treatment.

H1b: Students receiving a treatment with a lecture that incorporates the handshake R.E.A.L. exercise will exhibit an increase in student performance over students receiving a traditional lecture treatment.

H1c: Students receiving a treatment with a lecture that incorporates the wireless R.E.A.L. exercise will exhibit an increase in student performance over students receiving a traditional lecture treatment.

H1d: Students receiving a treatment with a lecture that incorporates the Bluetooth R.E.A.L. exercise will exhibit an increase in student performance over students receiving a traditional lecture treatment.

H1e: Students receiving a treatment with a lecture that incorporates the network speed R.E.A.L. exercise will exhibit an increase in student performance over students receiving a traditional lecture treatment.

H1f: Students receiving a treatment with a lecture that incorporates the network management R.E.A.L. exercise will exhibit an increase in student performance over students receiving a traditional lecture treatment.

H1g: Students receiving a treatment with a lecture that incorporates the types of attack R.E.A.L. exercise will exhibit an increase in student performance over students receiving a traditional lecture treatment.

H1h: Students receiving a treatment with a lecture that incorporates the hacking R.E.A.L. exercise will exhibit an increase in student performance over students receiving a traditional lecture treatment.

As the field of computing education continues to mature, more research is being conducted evaluating the impact of teaching strategies on students. A standard practice in educational research is to measure short retention. Powner and Allendoerfer (2008) researched the effectiveness of two different active learning strategies to traditional lecture. The research goal was to evaluate if the active learning approaches would improve the short term retention of the students in the study. After comparing the two treatments, no statistically significant difference was found. However, short-term retention as a variable is common in education research. It is with this background that the following hypothesis is offered:

H2: Students receiving a treatment with a lecture that incorporates a R.E.A.L. exercise will exhibit an increase in short-term retention over students receiving a traditional lecture treatment. H2a-H2h are the sub-hypotheses representing the eight treatments.

H2a: Students receiving a treatment with a lecture that incorporates the network R.E.A.L. exercise will exhibit an increase in short-term retention over students receiving a traditional lecture treatment.

H2b: Students receiving a treatment with a lecture that incorporates the handshake R.E.A.L. exercise will exhibit an increase in short-term retention over students receiving a traditional lecture treatment.

H2c: Students receiving a treatment with a lecture that incorporates the wireless R.E.A.L. exercise will exhibit an increase in short-term retention over students receiving a traditional lecture treatment.

H2d: Students receiving a treatment with a lecture that incorporates the Bluetooth R.E.A.L. exercise will exhibit an increase in short-term retention over students receiving a traditional lecture treatment.

H2e: Students receiving a treatment with a lecture that incorporates the network speed R.E.A.L. exercise will exhibit an increase in short-term retention over students receiving a traditional lecture treatment.

H2f: Students receiving a treatment with a lecture that incorporates the network management R.E.A.L. exercise will exhibit an increase in short-term retention over students receiving a traditional lecture treatment.

H2g: Students receiving a treatment with a lecture that incorporates the types of attack R.E.A.L. exercise will exhibit an increase in short-term retention over students receiving a traditional lecture treatment.

H2h: Students receiving a treatment with a lecture that incorporates the hacking R.E.A.L. exercise will exhibit an increase in short-term retention over students receiving a traditional lecture treatment.

During the literature review for this study, the researcher found long term retention as a common dependent variable in education research. Ruhl et al. (1987) used the pause approach by stopping 45-minute lecture three times with two-minute breaks. During the breaks, students would compare notes. At the same time, a separate group was exposed to lecture only. Both groups were tested for short-term and long-term retention.

Short-term retention was measured after the lecture where students were given three minutes to write down all they could remember graded according to the number of correct facts reported. A multiple choice test was given 1.5 weeks after the final lectures to measure long-term retention. Both short-term and long-term retention were improved using the pause method. From this literature search, we offer the following hypothesis:

H3: Students receiving a treatment with a lecture that incorporates a R.E.A.L. exercise will exhibit an increase in long-term retention over students receiving a traditional lecture treatment. H3a-H3h are the sub-hypotheses representing the eight treatments.

H3a: Students receiving a treatment with a lecture that incorporates the network R.E.A.L. exercise will exhibit an increase in long-term retention over students receiving a traditional lecture treatment.

H3b: Students receiving a treatment with a lecture that incorporates the handshake R.E.A.L. exercise will exhibit an increase in long-term retention over students receiving a traditional lecture treatment.

H3c: Students receiving a treatment with a lecture that incorporates the wireless R.E.A.L. exercise will exhibit an increase in long-term retention over students receiving a traditional lecture treatment.

H3d: Students receiving a treatment with a lecture that incorporates the Bluetooth R.E.A.L. exercise will exhibit an increase in long-term retention over students receiving a traditional lecture treatment.

H3e: Students receiving a treatment with a lecture that incorporates the network speed R.E.A.L. exercise will exhibit an increase in long-term retention over students receiving a traditional lecture treatment.

H3f: Students receiving a treatment with a lecture that incorporates the network management R.E.A.L. exercise will exhibit an increase in long-term retention over students receiving a traditional lecture treatment.

H3g: Students receiving a treatment with a lecture that incorporates the types of attack R.E.A.L. exercise will exhibit an increase in long-term retention over students receiving a traditional lecture treatment.

H3h: Students receiving a treatment with a lecture that incorporates the hacking R.E.A.L. exercise will exhibit an increase in long-term retention over students receiving a traditional lecture treatment.

Freeman et al. (2014) conducted a meta-analysis of over 200 studies on the use of active learning strategies in the fields of science, engineering, and mathematics. The researchers discovered that by employing the active learning strategies student engagement improved, which in turn was linked to better student performance. The researchers reported that engagement was an important part of learning. The value of engagement as a dependent variable in conducting educational research is supported empirically by the Freeman et al. (2014) study. It is with this background knowledge that the following hypothesis is offered:

H4: Students receiving a treatment with a lecture that incorporates a R.E.A.L. exercise will exhibit an increase in student engagement over students receiving a traditional lecture treatment. H4a-H4h are the sub-hypotheses representing the eight treatments.

H4a: Students receiving a treatment with a lecture that incorporates the network R.E.A.L. exercise will exhibit an increase in student engagement over students receiving a traditional lecture treatment.

H4b: Students receiving a treatment with a lecture that incorporates the handshake R.E.A.L. exercise will exhibit an increase in student engagement over students receiving a traditional lecture treatment.

H4c: Students receiving a treatment with a lecture that incorporates the wireless R.E.A.L. exercise will exhibit an increase in student engagement over students receiving a traditional lecture treatment.

H4d: Students receiving a treatment with a lecture that incorporates the Bluetooth R.E.A.L. exercise will exhibit an increase in student engagement over students receiving a traditional lecture treatment.

H4e: Students receiving a treatment with a lecture that incorporates the network speed R.E.A.L. exercise will exhibit an increase in student engagement over students receiving a traditional lecture treatment.

H4f: Students receiving a treatment with a lecture that incorporates the network management R.E.A.L. exercise will exhibit an increase in student engagement over students receiving a traditional lecture treatment.

H4g: Students receiving a treatment with a lecture that incorporates the types of attack R.E.A.L. exercise will exhibit an increase in student engagement over students receiving a traditional lecture treatment.

H4h: Students receiving a treatment with a lecture that incorporates the hacking R.E.A.L. exercise will exhibit an increase in student engagement over students receiving a traditional lecture treatment.

Hypotheses 1, 2, 3, and 4 were focused on student performance, STR, LTR, and student engagement with respect to the course objectives for the IS data communication and networking course, which is a classic practice in IS pedagogy research (Attaway et al., 2011; Crossgrove & Curran, 2008; Hodges, 2020; Luo et al., 2016; Porter et al., 2013; Ruhl et al., 1987; Surendran et al., 2005; Wiggins et al., 2017).

3.2 Research Design

The research study used a quasi-experimental design, given that the students could not be randomly assigned into groups and that the groups may be unequal in terms of students' demographics (Campbell & Stanley, 2015). Students were allowed to self-select their courses and course sections within the university of the study. Therefore, students could not be randomly assigned, nor could equal numbers of students be required to be enrolled in each section of the course. The quasi-experiment research design did not have full control of potential confounding variables because the participants were not randomly assigned and used natural groups that existed before the research study took place (Bhattacherjee, 2012; R. B. Johnson & Christensen, 2019; Shadish & Luellen, 2005).

To test the research hypotheses proposed in this study, a non-equivalent comparison group design was used, as shown in Table 1. This design consisted of two groups: an experimental group and a comparison/control group. Each group was given a pre-test. Then, after the experimental treatment had been administered to the experimental group only and the other group was administered a traditional lecture treatment, each group was given a post-test (R. B. Johnson & Christensen, 2019). Data were collected before and after applying treatments.

Table 1. Non-Equivalent Comparison-Group Design for Study of Treatment Conditions.

Groups	Pre-test Measure	Treatment Conditioning	Post-test Measure
Experimental	Pre-Quiz (5 Questions) O_1	Teach using R.E.A.L. treatments (active learning strategies) X_1	Post-Quiz (5 Questions) O_2
Control/Comparison	Pre-Quiz (5 Questions) O_1	Teach using traditional lecture	Post-Quiz (5 Questions) O_2

Note: (R. B. Johnson & Christensen, 2019; Shadish et al., 2002).

Additionally, a crossover design, as shown in Table 2, was used. One group received the R.E.A.L. treatment, while the other group served as the control and received a traditional lecture treatment. The process was reversed for the next topic, with the first group receiving the traditional lecture treatment and the second group receiving the R.E.A.L. treatment (R. B. Johnson & Christensen, 2019; Shadish et al., 2002). The crossover format ensured that all students were exposed to both teaching methods and made certain any effects of the research study were shared equally (Neuman, 2006). As shown in Table 2, the crossover occurred multiple times. Each group received a total of four treatments with R.E.A.L. treatments and four traditional lecture treatments covering the eight topic areas.

Table 2. Overview of the R.E.A.L. Treatments Crossover Design.

Sec	Single Networks	Single Networks	Wireless Networks	Wireless Networks	TCP/IP	TCP/IP	Net Apps	Net Apps
1	Treatment	Lecture	Treatment	Lecture	Treatment	Lecture	Treatment	Lecture
2	Lecture	Treatment	Lecture	Treatment	Lecture	Treatment	Lecture	Treatment

All students took an identical demographic survey, pre-tests, post-tests, engagement surveys, exams, and a perception survey. Figure 2 shows the order of the research design.

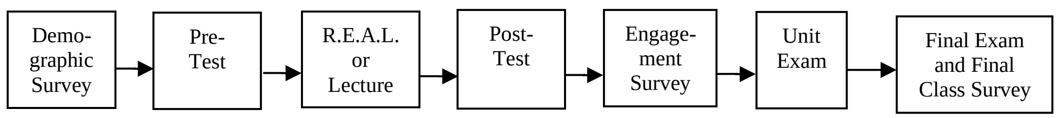

Figure 2. Order of Quasi-Experimental Research Design.

Appendix B, the demographic survey, was administered by a proctor on the first day of the course. This survey was used to collect student information, including students' goals, expectations, and subject matter interest. The demographic survey enabled the researcher to see how responses varied between groups in the study according to age, gender, ethnicity, and other characteristics to get a clear picture of the study participants.

The pre- and post-tests for each unit contained the same five questions. The pre-test was taken before the treatments and measured the student's knowledge of the topic before the intervention. The post-test and student engagement survey were performed immediately after the traditional lecture-based treatment or the treatment containing the R.E.A.L. exercise. The post-test measured the amount of learning gained after the student completed the treatment. The student engagement survey measured student engagement using a seven-point rating scale to provide gradated choices with responses ranging from *Strongly Agree* to *Strongly Disagree*. The questions in the student engagement survey corresponded to the researcher's objectives, adhered to the identified conditions of questionnaire construction (R. B. Johnson & Christensen, 2019), and were a variation of survey instruments used in other active learning research in IS (Giacaman & De Ruvo, 2018; Sibona et al., 2018). Survey questions were asked regarding the level of engagement experienced by the students during the treatment or lecture, the level of understanding of course-related concepts, the level of learning of course content, and if the treatment or lecture was a good review of the topic covered. The last question was asked to determine if the treatment or lecture was relevant to the course. A copy of the survey can be found in Appendix C. Capturing the students' responses directly following the treatment allowed the students to provide immediate feedback while the experiences were still fresh in their minds.

A unit exam was taken at the end of each unit. There was a total of four unit exams, with an exam covering each unit-single networks, wireless, TCP/IP, and networked applications and security. A subset of exam questions from the unit exams measured the students' STR for each unit. A table of the mappings for each question from each unit exam can be found in Appendix D. A comprehensive final exam was given at the end of the semester. A subset of exam questions from the comprehensive final exam measured the students' long-term retention of the concepts covered the entire semester. A table of the treatment mappings for each question from the comprehensive final exam can be found in Appendix E.

The students were given a final course perception survey. A copy of the survey with the complete list of questions for this survey can be found in Appendix F. The final course perception survey based on the Assessing Student Perspective of Engagement in Class Tool (ASPECT) survey (Wiggins et al., 2017) was administered to measure the perception of student engagement, instructor support, and active learning treatments. The survey instrument contained 17 questions on the VGW, PE, and IC, using a seven-point Likert scale from strongly agree to strongly disagree, and one open-ended question requesting additional information about the perceived value of the R.E.A.L. treatments, the course in general, and the students' preferred style of instruction.

Student performance was measured by comparing scores from the pre- and post-tests created by the researcher. STR was measured by items included in each of the four-unit exams focused on the treatment topics. LTR was measured through a subset of items on the comprehensive final exam. Student engagement was measured using a single-item scale after each treatment. The final class perception survey measured students' perceptions pertaining to the course as a whole based on VGW, PE, and IC.

3.3 R.E.A.L. Treatments

The R.E.A.L. treatments were active learning activities that accompanied a lecture and had the following characteristics: a well-defined start and end, a focused objective, easy-to-read, and easy-to-follow directions along with a feedback component (Paetzold & Melby, 2008; Wu et al., 2016). The R.E.A.L. treatments were structured activities designed to reinforce concepts covered in the course. A backward design approach, with Kolb's Experiential Learning Cycle as the framework (Kolb, A., 2005; Kolb, D., 2014), was used to develop the active learning experiences and instructional techniques that were focused on the student learning outcomes for the course (Handelsman et al., 2004). The activities were designed to engage students in an effort to assist in their understanding of how IS data communication and networking concepts actually work.

They were timed to fit, with their accompanying lecture, within a fifty-minute class session.

The R.E.A.L. treatments required deep processing tactics, such as analyzing, and offered opportunities to explore problems and challenges in a real-world context. In contrast, the lecture-only treatments promoted more surface learning, like memorization (Bonwell, 1996; Meyers & Jones, 1993; Prince, 2004). The R.E.A.L. treatments required coordination between the teacher and students to ensure in-class formative and summative assessments include rapid feedback. The R.E.A.L. treatments were tested in a pilot study during the 2018-2019 academic year. While the students generally had a favorable response to the R.E.A.L. treatments during the pilot study, many of the R.E.A.L. treatments had to be modified to provide the optimal constructivist educational experience. The R.E.A.L. treatment handouts are included in Appendix G.

3.4 Description of Course

The setting for this study was an IS and technology department at a public 4-year state university located in the southeastern part of the United States that offers both undergraduate and graduate programs. The subjects in the study were students in the undergraduate program. The two sections of the IS data communication and networking course, taught by the researcher, were the basis for this study, and students were exposed to both lectures that included R.E.A.L. treatments and the traditional lecture-only treatments. The quasi-experimental study took place during the Fall 2019 semester with 36 students enrolled. The two sections met at 10:10 am and 12:20 pm, respectively, on

Mondays, Wednesdays, and Fridays for fifty minutes each day. Both sections met in the same building but in different rooms.

The IS data communication and networking course is a “core” course used to satisfy the program requirements for undergraduate IS, IT, and HI degree programs. Some non-major students also enroll in the course as an elective. This course serves as a prerequisite for many upper level IS and IT courses and is typically offered in the fall, spring, and summer semesters. The prerequisite for the course is either an introductory to information systems in organizations or an introductory technology organizations course.

The course is an introduction to IS data communication, computer networking, and networking operating systems. The course covers the following topics: basic concepts of data transmission, network architectures, communications devices, and communication protocols. The course is divided into four units covering various topics discussed in networking: single networks, wireless networks, TCP/IP internetworking, and network applications. The textbook used in this study was *Business Data Networks and Security* (Panko & Panko, 2019). Table 3 displays the content and exam outline for the course.

The first week of the semester was introductory to the course, and no lectures took place. The first unit began in Week 2 and focused on single networks. It was approximately four weeks in duration, covering Chapters 1, 2, and 5. This unit included topics such as core network concepts and terminology, network standards, and Ethernet-switched single local area networks. The first unit exam concluded this unit.

The second unit focused on wireless network technology and was approximately three and a half weeks in duration and covered Chapters 6 and 7. This unit included key terms and concepts such as radio signal propagation, service bands and bandwidth, wireless LAN operation, the security of wireless LANs, and other wireless technologies (e.g., Bluetooth, Near Field Communication, Wi-Fi direct, Zigbee, and Z-Wave). The second unit exam ended this unit.

The third unit of the course, covering Chapters 8, 9, and 10, focused on TCP/IP internetworking and carrier wide area networks and was approximately four weeks in duration. This included key terms and concepts related to TCP/IP such as IP routing, routers processing packets, IPv4, IPv6, TCP, masks, IP subnetting, other TCP/IP standards (e.g., domain name system, DHCP servers, simple network management protocol, dynamic routing protocols), IPsec, virtual private networks, security associations, and SSL/TLS VPNs. Carrier WAN topics included local area networks, metropolitan area networks, wide area networks, residential wired internet access (e.g., cable modem and ADSL), cellular data service, wired business WANs, and carrier WAN services. The third unit exam concluded this unit.

The fourth and final segment of the course focused on network applications, network management, and network security, was approximately two and a half weeks in duration and covered Chapters 3, 4, and 11. This unit examined key terms and concepts related to networked applications and application architecture, virtualization and agility, the World Wide Web, e-mail, voice over IP, peer-to-peer applications, network quality of service, network design, centralized network management, software-defined networking, security breaches, types of security attacks, types of attackers, protecting dialogues cryptographically, authentication, and firewalls and intrusion detection systems. This unit concluded with the fourth unit exam.

The comprehensive final exam and the class perception survey were taken in week seventeen. The final exam consisted of key terms and concepts from all eleven chapters of the textbook.

Table 3. Course Outline for Content and Exams for an IS Data Communication and Networking Course.

Weeks	Content	Assessment
Weeks 2-5	Single Networks Chapter 1 Chapter 2 Chapter 5	Exam 1 • Multiple Choice • Fill in the Blanks • Short Discussion • Charts
Weeks 6-9	Wireless Networks Chapter 6 Chapter 7	Exam 2 • Multiple Choice • Fill in the Blanks • Short Discussion • Charts
Weeks 10-13	TCP/IP Chapter 8 Chapter 9 Chapter 10	Exam 3 • Multiple Choice • Fill in the Blanks • Short Discussion • Charts
Weeks 14-16	Networked Apps and Security Chapter 11 Chapter 3 Chapter 4	Exam 4 • Multiple Choice • Fill in the Blanks • Short Discussion • Charts
Weeks 17	Comprehensive Final Exam Chapters 1-11	• Multiple Choice • Fill in the Blanks • Short Discussion • Charts

3.5 Description of Participants

Students enrolled in the Fall 2019 semester in the IS data communication and networking course at a southeastern United States university were the population for the study. The author received IRB approval (Appendix H) to perform the study in the classroom setting. The study began with the initial consent form and the demographic survey administered by a proctor on the first day of the course. The students were provided information about the study and their voluntary participation. All students enrolled in the IS data communication and networking course were invited to participate in this study. Participants were required to be at least 18 years of age. These two items were collected and kept in a secure location until the semester ended. Identifying information was removed, and the data were compiled after final grades were submitted. The student informed consent document is included in Appendix I.

Students in the study, as shown in Table 4, were 61% (22) male and 39% (14) female and represented three ethnic groups: White/Caucasian 50% (18), African American 33% (12), and Asian 17% (6). The students were enrolled in three different majors: IS, IT, and HI. Nearly all, 94% (34), were aged 24 or younger. One student did not report their age. No students dropped the course or missed any of the R.E.A.L. treatments.

Table 4. Demographics of Participating Students Used in the Study of Treatment Conditions.

Variable		Frequency	Percentage
Age			
	19-21	18	50.000
	22-24	16	44.444
	25-older	1	02.778
	unknown	1	02.778
Ethnicity			
	African American	12	33.333
	Asian American	0	00.000
	Asian	6	16.667
	White	18	50.000
Major			
	IS	10	27.778
	IT	11	30.556
	HI	15	41.667
Gender			
	Male	22	61.111
	Female	14	38.8889

Note. *N* = 36; IS = Information Systems; IT = Information Technology; HI = Health Informatics.

3.6 Description of Researcher

The researcher was the instructor for the course used in the study and is an African American female. The researcher taught both sections using the same textbook, course outline, and course objectives and administered the same quizzes, unit exams, and comprehensive final exam to control for internal validity (Bhattacherjee, 2012; Neuman, 2006). The researcher taught the IS data communication and networking course as a member of the faculty for four years prior to the study and taught other computing courses for an additional eight years. The researcher also participated in an active learning initiative at the university that required the use of various active learning strategies in a course redesign. The instructor has attended conferences and workshops focused on active learning and evidence-based teaching.

3.7 Measurement and Variables

The independent variable in the study was the method of instruction — a lecture accompanied by a R.E.A.L treatment as compared to a traditional lecture alone. The dependent variables in the study were as follows:

1. Student performance. Student performance was measured via a five-question pre- and post-test given before and after each treatment (R.E.A.L. treatment or traditional lecture treatment).
2. Short-Term Retention. Short-term retention was measured by a subset of ten questions from the in-class unit exam covering the specific unit topic.
3. Long-Term Retention. Long-term retention was measured via a subset of twenty questions from the in-class comprehensive final exam.

4. Student Engagement. Student engagement was measured via a five-question survey after each lecture, regardless of whether the lecture was traditional or R.E.A.L.
5. Student Perception. A student's final perception of the course was measured via a survey based on the ASPECT Survey, which measured the student's perception of active learning in a classroom setting. It used the exact same questions as the ASPECT survey, with one open end question added by the researcher. The open-ended question asked for additional comments about the value of the active learning activities/exercises, the course in general, or the student's preferred style of instruction. The constructs used in this study were VGW, measured via survey questions 1-9; PE, measured via survey questions 10-12; and IC, measured via survey questions 13-16.

Demographic variables, including age, gender, ethnicity, and major, were collected as potential control variables. (Freeman et al., 2007; Umbach & Wawrzynski, 2005).

3.8 Pilot Study

The research began with a pilot study in Spring 2019 that involved 42 participants enrolled in the course. The participants were 74% (31) male and 26% (11) female. The median age was 21 years old, with most of the participants falling into the traditional college age range (18-23 years old). The oldest participant was 34 years old, and one participant's age was unreported. The class consisted of students enrolled in three majors: IS, IT, and HI. Four ethnicities were represented in the study: White 52.3% (22), African American 30.9% (13), Asian 9.5% (4), and Other 7.1% (3). Participants were selfenrolled in two sections of IS data communication and networking course as an intact group. The pilot study had three aims: (1) to test the feasibility and logic of the R.E.A.L. treatments, (2) to create and test questions for unit and final exams measuring STR and LTR, and (3) to test and improve the survey instruments used to capture student demographics, engagement, and final class perceptions.

Various R.E.A.L. treatments were tested during the pilot study. The R.E.A.L. treatments were designed to produce improved student learning outcomes over the lecture-only treatments. The R.E.A.L. treatments included: modified lectures (15 minutes of lecture mixed with 10-minute hands-on activity), think-pair-share, concept maps, entry and exit quizzes, crossword puzzle vocabulary review, case studies, and one-minute paper reflections. New teaching strategies used during the active learning treatments included case studies, how-to simulation videos (Barata et al., 2013a, 2013b; Kaufman & Ireland, 2016), problem-solving tasks, reflection-based activities, and hands-on course modules (i.e., command line exercises, LAN analyzing software, etc.). Supplementing the lecture with additional teaching strategies created a win-win situation for the students by allowing them to investigate and experience various real-world and modeled scenarios (Herreid & Schiller, 2013), helping students to gain a deeper understanding of the content using trial and error through simulations (Kaufman & Ireland, 2016), practicing for the actual certification exams (Gomillion, 2017), building critical thinking skills (Furse & Ziegenfuss, 2020), helping students construct their own knowledge through written and verbal reflection (Edwards, 2017), and engaging in visual processes (Powell, 2015). The students were exposed in more detail to additional new software tools used in industry by network professionals, such as Wireshark and MS Visio. As a result of the pilot study, a total of eight R.E.A.L. treatments were created or modified from existing assignments. The treatments in the pilot study were in alignment with the student learning outcomes, adequate time management of the exercises, and the communication of clear class requirements and instructions. The feedback provided by the students helped to identify any challenges with the treatments.

The pre-test, post-test, unit exam questions, demographics survey, student engagement survey, final exam, and final class perception survey were also piloted. The course used for the pilot study was modified to include four unit exams to measure STR and one comprehensive final exam for assessing long-term retention. The exam categories and textbook chapters were as follows: Introduction to Networks and Single Networks (Chapters 1, 2, and 5); Wireless Networks (Chapters 6 and 7); TCP/IP (Chapters 8, 9, and 10); and Networked Applications (Chapters 3, 4, and 11). Security implications were integrated into each exam. The exams consisted of multiple choice, fill-in-the-blank, fill-in-the-chart/diagram, and short answer questions. Exam questions were designed to be aligned with the student learning outcomes and require students to apply concepts learned to practical settings, more than a recall of general facts and definitions. The exams included questions involving higher-order thinking (Bonwell & Eison, 1991; Forehand, 2010; Kressler & Kressler, 2020), discipline-specific knowledge and skills (Angelo & Cross, 2012), real-world examples (Miri et al., 2007), and career preparation competencies (Angelo & Cross, 2012). The students were allowed to answer short answer questions using text or illustrations. The pilot study helped the researcher pre-test the exam questions and to ascertain the sampling structure and effectiveness of the active learning method (Bhattacherjee, 2012; Creswell & Clark, 2017).

The pilot study evaluated the survey instruments to be used in the study. The student demographic survey data captured initial student data, which was de-identified to maintain anonymity. The student engagement surveys were used to get specific feedback about the treatments and engagement. Modified versions of the survey instruments, based on the results of the pilot study, were used in the main study.

3.9 Data Collection

Data for this experiment were collected from six sources. First, the demographic survey was given to the students on the first day of class. The second source of measurements, examining the student's prior knowledge, (before the lesson) and knowledge of the topic (after the lesson), was extracted from the mean scores on each of the sets of pre-tests and post-tests administered during the lectures accompanied by R.E.A.L treatments and the traditional lecture alone. The third source of measurement examining STR was the mean scores for the subset of questions related to the topics covered on each of the unit exams. The fourth source of data, measuring LTR, was the mean scores for the subset of questions related to the topics covered the entire semester on the comprehensive final exam. All exam data for the study was collected by the instructor as a natural component of the course. The fifth source of measurement, examining the students' engagement, was data from the student engagement surveys taken at the end of every treatment. The sixth source of measurements of data, examining the students' perceptions of the course, was taken from the final class perception survey administered on the final day of class.

Formative assessments, such as weekly in-class verbal and written feedback, peer comments, and instructor evaluations/exam wrappers, were included along with the summative assessments used in the study. Formative assessment supports instruction and improves learning in the active learning classroom setting (Crisp, 2012; Keeley, 2011). The formative assessments were not graded but were used by the instructor to adjust her teaching and to provide the students with instant feedback on their understanding of the topic or concept (Gilboy et al., 2015; Keeley, 2011). After the data collection, data were analyzed using Microsoft Excel for Microsoft 365 Apps for enterprise Version 2301(Build 16026.20146 Click-to-Run) (Microsoft, 2018), IBM SPSS Statistics (Version 27), and statistical software R.404 using the Lavaan package (Rosseel, 2012).

3.10 Summary

This study was conducted using quantitative research methods to determine if active learning strategies improve student learning outcomes in an IS data communication and networking course. The study participants were 36 undergraduate college students enrolled in an IS data communication and networking course in the Fall 2019 semester. The research used anonymous demographic surveys, pre-test and post-test exams, student engagement surveys, scores for the subset of questions related to the topics covered on the unit exams, scores for the subset of questions related to the topics covered on the comprehensive final exam, and the final class perception survey.

CHAPTER IV

ANALYSIS AND RESULTS

Chapter IV presents the results of the study. Coverage of these results is broken into the following: (1) overview of analyses; (2) results of hypotheses testing with MANCOVA quantitative data analysis for testing Hypotheses 1-4; (3) structured equation modeling (SEM); (4) construct validity; (5) results of post hoc analysis results from an alternative statistical approach using MLM; and (6) summary.

4.1 Overview of Analyses

The following instruments and measures were used for the study: unit tests (same pre and post), engagement survey after each intervention (R.E.A.L. treatment or traditional lecture), unit exams (a subset of questions on four exams), comprehensive final exam (a subset of questions), and final class perception survey (measuring three constructs—VGW, PE, and IC).

4.1.1 Instrumentation/Measures

The study collected data from a total of 36 (*N* = 36) students enrolled in the IS data communication and networking course (via quizzes, exams, and self-administered surveys). Data collected included the following:

- Student data were collected from the demographic survey administered by a proctor on the first day of class. The survey collected demographics (age, gender, and ethnicity), educational aspirations, and subject matter interests.
- Identical unit pre- and post-tests were used to capture the student's prior knowledge before the intervention and the student's knowledge of the topic area after the intervention. Before the R.E.A.L. treatment (intervention) or traditional lecture, each participant took a five-question quiz on the topic matter. After the R.E.A.L. treatment (intervention) or traditional lecture, a post-test, composed of identical questions from the pre-test, was also given.
- The student engagement survey was also administered immediately after the R.E.A.L. treatment (intervention) or traditional lecture. The survey consisted of five questions using a 1-7 scale ranging from strongly disagree to strongly agree.
- A total of four unit exams were administered to the participants. A subset of questions from the unit exams was used to measure the students' short-term retention.
- A comprehensive final exam was given to the participants. A subset of questions from the final exam was used to measure the students' long-term retention.
- The final class perception survey was administered at the end of the course. It is a multi-item scale instrument that measures the students' perception of active learning in the classroom. Three constructs were measured in the survey: VGW, PE, and IC.

4.2 Hypothesis Testing

The data for hypothesis testing was collected from implementing an active learning teaching strategy using R.E.A.L. treatments in conjunction with a lecture compared to a lecture-only teaching method.

4.2.1 Multivariate Analysis of Covariance (MANCOVA)

A Multivariate Analysis of Covariance (MANCOVA) with repeated measures was used to test the four hypotheses in the study. The MANCOVA was selected because the study included the instruction method as a categorical independent variable, the multiple dependent variables of student performance, STR, LTR, and student engagement, and the four control variables of age, ethnicity, major, and gender (Heale & Twycross, 2015; O'Brien & Kaiser, 1985). MANCOVA is a widely used technique for comparing the means of several dependent variables at once that are controlled by covariates (O'Brien & Kaiser, 1985). The MANCOVA takes the average mean of the dependent variable for the R.E.A.L. treatment group and the average dependent variable mean for the lecture-only group, then compares them to see if they differ (O'Brien & Kaiser, 1985). The differences in the two instructional methods, traditional lectures and active learning strategies, were compared in eight individual MANCOVAs for each of the eight distinct treatments.

4.2.2 Hypothesis Testing with MANCOVA Results

The data from the post-test was used in this study to analyze the mean of the dependent variable, student performance. The data from a subset of ten questions from the in-class unit exam were used to analyze the mean of the dependent variable STR. A subset of twenty questions from the in-class comprehensive final exam was used as data for the dependent variable long-term retention. Student engagement was data from a five-question survey given after each treatment or lecture. Participants were exposed to eight treatments, and the repeated measures MANCOVA indicated which treatments had a positive impact on the dependent variables using a p-value of 0.05 or less to determine a statistically significant result (Bhattacherjee, 2012).

4.2.3 Hypothesis 1

H1: Students receiving a treatment with a lecture that incorporates a R.E.A.L. exercise will exhibit an increase in student performance over students receiving a traditional lecture treatment.

The results of the MANCOVA shows there was a statistically significant difference in student performance based on the R.E.A.L. treatments *($F(8, 21) = 3.573$, $p = .009$; Wilk's $\Lambda = 0.424$, partial $\eta 2 = 0.576$)* in three out of the eight treatments, partially supported Hypothesis 1. Statistically significant results were obtained for the H1a Network treatment *($F(1,28) = 6.033$, $p = 0.021$, partial $\eta 2 = 0.177$)*, meaning that the mean for the H1a Network treatment *($M = 90.842$)* was significantly different than the lecture mean *($M = 75.533$)*. The H1b Handshake treatment *($F(1,28) = 15.405$, $p = .001$, partial $\eta 2 = 0.355$)* and the H1c Wireless treatment *($F(1,28) = 11.385$, $p = .002$, partial $\eta 2 = 0.289$)* produced results in the reverse direction of what was hypothesized, meaning that the mean for the H1b Handshake treatment (M = 49.800) and the H1c Wireless treatment (M = 86.842) were significantly lower than the lecture means for both hypothesis tests. Table 5 shows the summary data analysis of student performance when exposed to the eight R.E.A.L. treatments.

Table 5. Testing Hypothesis 1: R.E.A.L. → Student Performance.

Treatment	Mean-Treatment	Mean-Lecture	*F*-statistic	*p*-value	H-supported?
H1a: Network	90.842	73.533	6.033	0.021	Yes
H1b: Handshake	49.800	77.684	15.405	0.001	No (reverse direction)
H1c: Wireless	86.842	98.667	11.385	0.002	No (reverse direction)
H1d: Bluetooth	76.533	84.316	3.278	0.081	No
H1e: Network speed	67.684	78.067	2.194	0.150	No
H1f: Network management	69.933	76.421	3.159	0.086	No
H1g: Types of attacks	87.842	86.133	0.090	0.767	No
H1h: Hacking	91.600	88.158	0.379	0.543	No

Control variables, also known as covariates, must be measured because they can impact the study's dependent variables and the results (Bhattacherjee, 2012). Control variables are variables that do not change over time (Bhattacherjee, 2012). The researcher held the control variables constant to allow for more precise detection of the effects of the measured independent variables (Bhattacherjee, 2012). The control variables of age, ethnicity, major, and gender impacted two of the eight R.E.A.L. treatments. Statistically significant results were obtained for the H1b Handshake treatment for ethnicity *($F(1,28) = 5.891$, $p = 0.022$, partial $\eta 2 = 0.174$)*. H1c Wireless treatment had significant results obtained for the control variables of age *($F(1,28) = 12.819$, $p = 0.001$, partial $\eta 2 = 0.314$)*, ethnicity *($F(1,28) = 5.566$, $p = 0.026$, partial $\eta 2 = 0.166$)*, and major *($F(1,28) = 5.891$, $p = 0.184$, partial $\eta 2 = 0.184$)*. The full statistical analysis for all control variables can be found in Appendix J.

4.2.4 Hypothesis 2

H2: Students receiving a treatment with a lecture that incorporates R.E.A.L. treatment will exhibit an increase in short-term retention over students receiving a traditional lecture treatment.

Short-term retention was a formative measure and each of the questions that were included needed to be checked to make sure that collinearity issues did not exist between each of the indicators (Hair et al., 2018). In order to assess the level of collinearity, SPSS was used to check the Variance Inflation Factor (VIF) and all values were below a VIF score of 3, which indicates no collinearity issues. The results of the MANCOVA show there was not a statistically significant difference in short-term learning based on the R.E.A.L. treatment ($F(8, 22) = 1.172$, $p = .359$; Wilk's $\Lambda = 0.701$, partial $\eta 2 = .299$). Therefore, this study failed to support H2. Table 6 shows the summary data analysis of short-term retention when exposed to the eight active learning treatments.

The control variable of age impacted two of the eight R.E.A.L. treatments. Statistically significant results were obtained for the H2e Network speed treatment ($F(1,28) = 5.709$, $p = 0.024$, partial $\eta 2 = 0.164$) and H2f Network management treatment ($F(1,28) = 5.654$, $p = 0.024$, partial $\eta 2 = 0.163$). The full statistical analysis for all control variables can be found in Appendix J.

4.2.5 Hypothesis 3

H3: Students receiving a treatment with a lecture that incorporates a R.E.A.L. treatment will exhibit an increase in long-term retention over students receiving a traditional lecture treatment.

Table 6. Testing Hypothesis 2: R.E.A.L. → Short-Term Retention.

Treatment	Mean-Treatment	Mean-Lecture	*F*-statistic	*p*-value	H-supported?
H2a: Network	9.600	10.033	0.002	0.969	No
H2b: Handshake	20.550	21.075	0.015	0.902	No
H2c: Wireless	23.300	23.870	1.560	0.222	No
H2d: Bluetooth	8.470	7.600	2.588	0.119	No
H2e: Network speed	6.650	7.330	1.082	0.307	No
H2f: Network management	20.600	20.125	0.110	0.743	No
H2g: Types of attacks	9.250	9.100	0.574	0.455	No
H2h: Hacking	7.533	8.625	3.706	0.064	No

Short-term retention was a formative measure and each of the questions that were included needed to be checked to make sure that collinearity issues did not exist between each of the indicators (Hair et al., 2018). In order to assess the level of collinearity, SPSS was used to check the VIF and all values were below a score of 3 which indicates no collinearity issues. The results of the MANCOVA show there was not a statistically significant difference in long-term learning based on the R.E.A.L. treatments *($F(8, 22) = 1.135$, $p = .379$; Wilk's $\Lambda = 0.708$, partial $\eta 2 = .292$)*. Therefore, this study failed to support H3. Table 7 shows the summary data analysis of long-term retention when exposed to the eight active learning treatments. None of the control variables had a significant impact on the eight R.E.A.L. treatments. The full statistical analysis for all control variables can be found in Appendix J.

Table 7. Testing Hypothesis 3: R.E.A.L. → Long-Term Retention.

Treatment	Mean-Treatment	Mean-Lecture	*F*-statistic	*p*-value	H-supported?
H3a: Network	11.025	9.800	3.828	0.060	No
H3b: Handshake	1.200	0.800	1.787	0.192	No
H3c: Wireless	6.000	5.870	0.133	0.718	No
H3d: Bluetooth	2.000	1.900	0.662	0.422	No
H3e: Network speed	6.050	6.470	0.173	0.681	No
H3f: Network management	15.930	15.400	0.797	0.379	No
H3g: Types of attacks	3.700	2.930	4.125	0.052	No
H3h: Hacking	3.470	3.750	0.623	0.436	No

4.2.6 Hypothesis 4

H4: Students receiving a treatment with a lecture that incorporates a R.E.A.L. exercise will exhibit an increase in student engagement over students receiving a traditional lecture treatment.

The student engagement scale was a reflective variable that needed to be analyzed for construct validity. To test the construct validity exploratory factor analysis (EFA) was conducted. Construct validity is a series of tests that determines how well a measurement scale accurately assesses a theoretical construct (Bhattacherjee, 2012). Construct validity includes reliability, which measures the degree that a construct is consistent (Bhattacherjee, 2012). Reliability was assessed using Cronbach alpha. EFA was conducted using a factor analysis in SPSS.

A principal component analysis with a data reduction method used to reduce a given set of items into a smaller number of variables based on correlation, was used as the extraction method to identify the components that emerge from the data (Bhattacherjee, 2012). The components extracted should roughly cluster based on how each construct's intended measurement items are correlated with one another. The main result of principal components analysis is the rotated component matrix, often known as the loadings, which includes the estimates of the correlations between every variable and the extracted components (Bhattacherjee, 2012). The rotated component matrix gives the values of the loadings and helps to determine what the components represent (Bhattacherjee, 2012). A varimax rotation was utilized since the data was regarded as orthogonal since the measurement items should differ in correlation based on the latent construct they are measuring. Each loading reported in the rotated matrix is the correlation between the item and its extracted component (Bhattacherjee, 2012). These results are interpreted as how well a measurement item is correlated with the construct it is intended to measure.

Following research convention, items are kept for further analyses if their loadings on pertinent constructs are higher than 0.60 (Bhattacherjee, 2012) while remaining lower than 0.4 on constructs they are not intended to measure (Suhr, 2006). All of the questions except Student Engagement Question 5 loaded at 0.829, 0.882, 0.892, and 0.888, respectively. Student Engagement 5, loaded with a score of -0.534 and was reversed coded. Question 5 should be removed but was retained temporarily to see the impact this question would have on the reliability of the construct. The factor loads for the first four student engagement questions once questions 5 was removed were 0.834, 0.903, 0.912, and 0.880, respectively.

Methods also were used to evaluate the reliability of the student engagement measure in this study (Bhattacherjee, 2012). Reliability evaluates the degree to which a scale yields consistent results across items (Bhattacherjee, 2012). The consistency of measurement is also described as the internal reliability of the construct (Bhattacherjee, 2012). Reliability was measured using Cronbach's alpha, where levels above .70 are considered good estimates of reliability (Bhattacherjee, 2012). Leaving Student Engagement Question 5 resulted in a Cronbach's alpha of .537 for the student engagement construct, which is far below the .70 threshold. Removing Student Engagement Question 5 resulted in a Cronbach's alpha of .905, which is above the threshold. Each of the four remaining student engagement questions were summed together for the MANCOVA analysis.

The results of the MANCOVA show that there was not a statistically significant difference in student engagement based on the R.E.A.L. treatment *($F (8, 22) = 0.799$, $p = .609$; Wilk's $\Lambda = .775$, partial $\eta 2 = .225$).* This study did not support H4. Table 8 shows the summary data analysis of student engagement retention when exposed to the eight active learning treatments. None of the control variables had a significant impact on the eight R.E.A.L. treatments. The full statistical analysis for all control variables can be found in Appendix J.

Table 8. Testing Hypothesis 4: R.E.A.L. → Student Engagement.

Treatment	Mean-Treatment	Mean-Lecture	*F*-statistic	*p*-value	H-supported?
H4a: Network	23.900	23.267	0.230	0.635	No
H4b: Handshake	23.200	22.500	0.001	0.981	No
H4c: Wireless	24.050	25.200	1.248	0.273	No
H4d: Bluetooth	23.133	22.800	0.028	0.869	No
H4e: Network speed	24.550	24.333	0.004	0.951	No
H4f: Network management	25.000	23.600	1.243	0.274	No
H4g: Types of attacks	23.950	24.267	0.011	0.918	No
H4h: Hacking	23.733	24.800	2.050	0.163	No

4.3 Structured Equation Modeling (SEM)

The study used MLM to analyze repeated measures data. MLM allowed the researcher to capture certain effects more precisely than running individual MANCOVAs or repeated measures MANCOVAs (Heck & Thomas, 2020). MLM has higher power during hypothesis testing in revealing effects and contrasts in the data (Heck & Thomas, 2020). Although MLM is computationally complex, it is being used more frequently in educational research to show where observations cluster within groups in a hierarchical data structure (Heck & Thomas, 2020).

4.4 Construct Validity

To test the construct validity of the instrument items on the Student Perception of Course Survey, exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were conducted. Construct validity includes reliability, convergent validity, which measures the degree to which constructs are similar; and discriminant validity, which measures the degree to which constructs differ (Bhattacherjee, 2012). All these analyses were conducted in this study. CFA was conducted to test the construct validity of the final perception survey items. EFA and CFA each test for convergent and discriminant validity. EFA was used to show the degree of intercorrelation between individual survey items (Bhattacherjee, 2012). CFA was used to show the degree of intercorrelation between constructs (Bhattacherjee, 2012). The final perception survey measured three constructs to be assessed for construct validity: VGW (Questions 1-9), PE (Questions 10-12), and IC (Questions 13-16).

4.4.1 Exploratory Factor Analysis

EFA looks for patterns between measurement items, specifically assessing how strongly a set of items for a latent construct are associated with one another while being more weakly associated with items that do not measure that latent construct. While EFA is not as rigorous as confirmatory factor analysis, EFA aids in defining the number of latent constructs underlying a study’s data (Bhattacherjee, 2012; Heale & Twycross, 2015) and helps reveal the data’s underlying factor model (Suhr, 2006). EFA was conducted on the constructs of the student perception of course survey using SPSS to test for the convergent and discriminant validity of survey items when items are allowed to correlate freely with one another (Suhr, 2006). To increase the validity of the measure, multi-item scales were used to measure the latent constructs (Diamantopoulos et al., 2012; R. B. Johnson & Christensen, 2019). EFA is used to determine validity and cannot be used on a single-item scale (Suhr, 2006). The demographic and engagement surveys used in the study consisted of single-item scales; therefore, construct validity assessments, including EFA, were not used for these scales.

Two items from the VGW scale, 8 and 9, were dropped because they did not load with the other scale items at the prescribed level, VGW8 was 0.392. VGW9 was 0.137. In EFA, PE2 was cross-loading to 0.469 and barely met the cross loading threshold of 0.4. However, PE2 was left in the analysis because the construct loaded strongly on its own construct and in CFA it demonstrated discriminant validity when compared to the other constructs (Bhattacherjee, 2012; Heale & Twycross, 2015; Suhr, 2006). All items for IC met the factor loading criteria and were kept. The EFA, therefore, supported the retention of 14 of the 16 total questions from the final perception survey. The rotated component matrix and the constructs are presented in Table 9.

Table 9. Rotated Component Matrix for the Student Perception of Course Survey.

Construct	Component		
	1	2	3
VGW1	0.895	0.018	0.157
VGW2	0.865	-0.097	-0.025
VGW3	0.798	0.014	0.255
VGW4	0.836	0.234	0.087
VGW5	0.915	0.072	0.233
VGW6	0.880	0.178	0.200
VGW7	0.638	0.335	0.303
IC1	0.100	0.837	0.111
IC2	0.023	0.929	0.114
IC3	0.089	0.939	0.177
IC4	0.138	0.836	0.347
PE1	0.287	0.123	0.899
PE2	0.469	0.285	0.794
PE3	0.052	0.332	0.880

Note: N = 36; Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalization; VGW = Value of Group Work; IC = Instructor Contribution; PE = Personal Effort.

4.4.2 Confirmatory Factor Analysis

In structural equation modeling (SEM), CFA is the technique used to assess the validity of measurement models (Heale & Twycross, 2015; Suhr, 2006) and is used to test exactly how well the calculated variables represent the number of constructs (Heale & Twycross, 2015; Suhr, 2006). CFA is regarded as a more rigorous approach and provides more confident results than EFA by allowing the researcher to test the hypothesis that a relationship exists between an observed variable and its underlying latent constructs (Suhr, 2006). Both CFA and EFA are based on linear statistical models, assume a normal distribution, and incorporate measured variables and latent constructs (Heale & Twycross, 2015; Suhr, 2006). However, CFA is used to confirm the measurement model while constraining measurement items to their focal constructs and not allowing free correlation between measurement items (Bhattacherjee, 2012; Heale & Twycross, 2015; Suhr, 2006). This allowed the researcher to hypothesize the model's relationships a priori and then statistically analyze each hypothesis contained in the model (Suhr, 2006). CFA was assessed using the statistical software R.404 using the lavaan package (Rosseel, 2012).

4.4.3 Convergent Validity and Reliability Estimation

Convergent validity describes how closely a measure connects to or converges on the construct that it is intended to measure (Bhattacherjee, 2012; Heale & Twycross, 2015). In CFA, convergent validity is assessed by examining standardized loadings of individual items, as well as the average variance extracted (AVE) of all items measuring a certain construct. AVE is derived by squaring the standardized loading of each item and averaging the squared loadings for the items related to a specific construct.

Therefore, AVE provides an overall assessment of convergent validity for the construct. A construct's AVE is considered acceptable if it is 0.50 or higher (Bhattacherjee, 2012; Heale & Twycross, 2015). In this study, the AVEs were above 0.5 for VGW (0.734), IC (0.798), PE (0.797), and ENG (0.770). Therefore, all constructs exhibited acceptable convergent validity (see Table 10). The Cronbach's alpha values for the three survey-based constructs VGW 0.939, IC 0.937, PE 0.921, and ENG 0.905, shown in Table 10, were all greater than 0.90, above the required level of 0.7.

Table 10. Standardized Loadings, Estimate, AVE, and Cronbach's Alpha for Student Perception of Course Survey.

Construct	Estimate	AVE	Cronbach's Alpha
VGW1	0.904	0.734	0.939
VGW2	0.796		
VGW3	0.826		
VGW4	0.784		
VGW5	0.946		
VGW6	0.873		
IC1	0.749	0.798	0.937
IC2	0.952		
IC3	0.993		
IC4	0.859		
PE1	0.858	0.797	0.921
PE2	0.988		
PE3	0.790		
ENG2	0.785	0.770	0.905
ENG3	0.932		
ENG4	0.908		

Note. VGW = Value of Group Work; IC = Instructor Contribution; PE = Personal Effort; ENG = Engagement.

Statistical methods also were used to evaluate reliability in the study (Bhattacherjee, 2012). The consistency of measurement is also described as the internal reliability of the construct (Bhattacherjee, 2012).

4.4.4 Discriminant Validity

Discriminant validity is the degree to which one construct varies from another construct and measures the uniqueness of constructs from each other (Bhattacherjee, 2012). This is important because, by demonstrating that indicators of one construct are different from (i.e., have little association with) those of other constructs, discriminant validity is established (Bhattacherjee, 2012). Inter-construct correlation is a means of analyzing how closely correlated constructs are to one another (Collier, 2020). According to Fornell and Larcker (1981), discriminant validity can be checked by comparing the loadings between the constructs and the square root AVE of each construct. Discriminant validity is met if the square root AVE of each construct is higher than the constructs' inter-construct correlation (Fornell & Larcker, 1981).

Table 11. Inter-Construct Correlations for CFA–Confirmatory Factor Analysis.

	ENG	IC	PE	VGW
ENG	(0.877)			
IC	-0.081	(0.893)		
PE	-0.067	0.346	(0.893)	
VGW	0.015	0.207	0.627	(0.857)

Note. ENG = Engagement; IC = Instructor Contribution; PE = Personal Effort; VGW = Value of Group Work.

Table 11 reports the matrix of inter-construct correlations, in which the terms that appear in the parentheses are the square root AVE for each construct. The square root of AVE in each construct (0.877, 0.893, 0.893, & 0.857) is higher than the corresponding inter-construct correlation, indicating acceptable discriminant validity was met (Collier, 2020).

4.4.5 Overall Evaluation of Construct Validity

The construct validity of a measurement scale evaluates how effectively it captures the theoretical construct that it is intended to measure (Bhattacherjee, 2012). Construct validity is determined by evaluating convergent validity, reliability, and discriminant validity (Bhattacherjee, 2012). For all four constructs used as measurements in this study, VGW, IC, PE, and ENG, the statistical requirements were met to establish good to excellent convergent validity, reliability, and discriminant validity.

4.5 Post Hoc Analysis Results

As the hypothesized relationships between the R.E.A.L. treatments and student performance were not supported by the data, indirect pathways were tested through a post hoc analysis using MLM. Multilevel models are designed for hierarchical data structures in which observations cluster within larger groups (Heck & Thomas, 2020). This analysis used MLM to account for the use of repeated measures where subjects were measured two or more times (Heck & Thomas, 2020). This study design featured natural nesting, with the repeated measured nested within individual students. Using all valid data from subjects, a multilevel regression model was tested using the lavaan package (Rosseel, 2012) in R 4.0.4. MLM can capture certain effects more accurately than individual MANCOVAs or repeated measures MANCOVAs. This is due to the study's dataset, in which some of the data were captured multiple times (treatment, pre-test, and the four dependent variables), and some data were captured only once (age, ethnicity, section number, major, gender). The categorical variables, gender and ethnicity, were coded as individual binary variables to be included in the individual MLM analysis, allowing the use of one regression equation to represent multiple groups and negating the need for separate equation models for each subgroup (Bhattacherjee, 2012; R. B. Johnson & Christensen, 2019; Rosseel, 2012).

MLM captures the different effects more accurately by separating the variables measured multiple times, within-subjects (Level 1), from those that are measured just once, between-subjects (Level 2; Heck & Thomas, 2020). An MLM procedure was used to examine the variance within-subjects and between-subjects. In MLM, the variance of the outcome variable is partitioned at the within-subjects (Level 1) and between-subjects (Level 2) levels, which not only corrects for the possible overestimation of standard errors but also allows researchers to make correct inferences about the relationship between variables at different levels (Heck & Thomas, 2020). Overestimation of standard errors did not occur in this study. The relationships among all variables, including hypothesized treatment, controls, dependent variables, and the VGW, IC, and PE variables were tested.

Employing the MLM processes allowed the researcher to get a more holistic picture of students' learning outcomes while being able to analyze clustered data and handle possible non-normal or missing data measured at varied times from subject to subject (Heck & Thomas, 2020). The MLM approach revealed interactions and mediated relationships among several of the study's variables. The within-subjects (Level 1) Inter-Construct Correlations table can be viewed in Appendix K. The variables used as between-subjects (Level 2) predictors were obtained from the student demographics survey (age) and the final class perception survey (PE and IC). The between-subjects (Level 2) Inter-Construct Correlations table can be viewed in Appendix L.

The MLM analysis resulted in support for several plausible relationships among the study's constructs. The within-subjects (Level 1) variables included the study's repeated measures, which were obtained from the student pre-tests, post-tests, engagement surveys, unit exams, and the final exam. In the MLM analysis, the active learning treatment significantly affected long-term retention (z-value = 2.148; p = 0.016). The active learning treatment did not significantly affect performance (z-value = 0.393; p = 0.348) or engagement (z-value = 0.851; p = 0.198); the active learning treatment affected short-term retention (z-value = -2.165; p = 0.015) but in the opposite direction hypothesized. The pre-test had a significant effect on short-term retention (z-value = 6.876; $p < 0.001$) and long-term retention (z-value = 2.226; p = 0.013) but not performance (z-value = 0.233; p = 0.408) or engagement (z-value = 0.152; p = 0.440). Time point significantly influenced performance (z-value = -4.389; $p < 0.001$), long-term retention (z-value = 3.251; p = 0.001), and engagement (z-value = 1.679; p = 0.047) but did not affect short-term retention (z-value = 0.479; p = 0.316). Additionally, short-term retention significantly impacted long-term retention (z-value = 4.012; $p < 0.001$).

In the original data analysis, the research did not indicate a direct effect of active learning on the four dependent variables. However, using MLM, several interaction effects at the within-subjects level were observed. Time point interacted with the pre-test's effect on performance (z-value = 6.095; $p < 0.001$), short-term retention (z-value =

-6.361; $p < 0.001$), and long-term retention (z-value = -2.683; $p = 0.021$). Time point also interacted with the active learning treatment's effect on long-term retention (z-value = -2.044; $p < 0.001$). Finally, engagement interacted with the active learning treatment's effect on short-term retention (z-value = 1.906; $p = 0.029$).

The between-subjects (Level 2) estimates indicated that engagement was impacted both the student's age (z-value = -2.669; $p = 0.004$) and whether the student was African American (z-value = 2.878; $p = 0.002$). Long-term retention was affected by the student's perception of instructor contribution (z-value = -2.353; $p = 0.010$) and whether the student was female (z-value = 2.199; $p = 0.014$). Performance was influenced by the student's perception of personal effort (z-value = 1.829; $p = 0.034$). Students who perceived they had worked hard in the course overall tended to perform better (Hu & Kuh, 2002). Finally, a student's perception of instructor contribution was significantly affected by whether the student was female (z-value = 2.042; $p = 0.021$), and if the student was African American (z-value = 2.550; $p = 0.006$). Table 12 shows the analysis of the main effects.

Because potential mediated relationships were implied in the model's main effects, indirect effects were tested using a mediation analysis. At the within-subjects level, the pre-test (z-value = 2.198; $p = 0.014$) and time point (z-value = -3.382; $p = 0.001$) each demonstrated a significant indirect effect on long-term retention through short-term retention; the active learning treatment did not indirectly affect long-term retention through short-term retention (z-value = -1.443; $p = 0.075$).

Table 12. Multilevel Model Main Effects Within and Between Subjects Used in the Study of Treatment Conditions.

	Estimate	*z*-value	*p*-value	Significant?
Within-Subjects (Level 1)				
R.E.A.L. Treatment → Performance	0.012	0.393	0.348	N
R.E.A.L. Treatment → STR	-0.584	-2.165	0.015	Y*
R.E.A.L. Treatment → LTR	0.187	2.148	0.016	Y
R.E.A.L. Treatment → Engagement	0.030	0.851	0.198	N
Pre-test → Performance	0.040	0.233	0.408	N
Pre-test → STR	0.243	6.876	< 0.001	Y
Pre-test → LTR	0.128	2.226	0.013	Y
Pre-test → Engagement	0.002	0.152	0.440	N
Time Point → Performance	-0.490	-4.389	< 0.001	Y
Time Point → STR	0.196	0.479	0.316	N
Time Point → LTR	0.826	3.251	0.001	Y
Time Point → Engagement	0.092	1.679	0.047	Y
STR → LTR	0.215	4.012	< 0.001	Y
Interaction Effects				
Time Point x Pre-test → Performance	0.718	6.095	< 0.001	Y
Time Point x Pre-test → STR	-0.400	-6.361	< 0.001	Y
Engagement x R.E.A.L. → STR	0.519	1.906	0.029	Y
Time Point x R.E.A.L. → LTR	-0.215	-2.044	0.021	Y
Time Point x Pre-test → LTR	-0.812	-2.683	0.004	Y
Between-Subjects (Level 2)				
PE → Performance	0.249	1.829	0.034	Y
IC → LTR	-0.221	-2.353	0.010	Y
Female → LTR	0.366	2.199	0.014	Y
Age → Engagement	-0.461	-2.669	0.004	Y
African American → Engagement	0.565	2.878	0.002	Y
Female → IC	0.262	2.042	0.021	Y
African American → IC	0.335	2.550	0.006	Y

Note. STR = Short-Term Retention; LTR = Long-Term Retention; IC = Instructor Contribution; PE = Personal Effort; R.E.A.L = Real World Experiences in Active Learning.
* = reversed significance.

Table 13. Multilevel Model Indirect Effects Within and Between Subjects Used in the Study of Treatment Conditions.

	Estimate	*z*-value	*p*-value	Significant?
Within-Subjects (Level 1)				
R.E.A.L. Treatment → STR → LTR	-0.254	-1.443	0.075	N
Pre-test → STR → LTR	0.008	2.198	0.014	Y
Time Point → STR → LTR	-0.196	-3.382	0.001	Y
Between-Subjects (Level 2)				
Female → IC → LTR	-0.069	-1.215	0.112	N
African American → IC → LTR	-0.089	-1.301	0.097	N

Note. STR = Short-Term Retention; LTR = Long-Term Retention; IC = Instructor Contribution; PE = Personal Effort; R.E.A.L. = Real-World Experiences in Active Learning.

At the between-subjects level, a student being female (*z*-value = -1.215; *p* = 0.112) or African American (*z*-value = -1.301; *p* = 0.097) did not indirectly influence long-term retention through IC as shown in Table 13.

Altogether, the MLM analysis revealed several significant direct effects, interaction effects, and indirect effects. The pre-test, which measured students' prior knowledge of material to be covered in each lesson, directly affected STR and LTR. Students' prior knowledge played a role in this outcome. Students came to class with prior knowledge attained from previous experiences and courses. One of the tenets of constructivism is that learning is an active process where students become active participants in their learning and make meaningful connections between prior knowledge, new learning, and the processes involved in learning (Bada & Olusegun, 2015). Time point interacted with the pre-test's effect on performance, indicating that the influence of the pre-test on performance increased over time. Time point interacted with the pre-test's effect on LTR, such that the influence of the pre-test on LTR significantly decreased over time.

In this analysis, ethnicity was a significant factor. The student being African American appeared to have a significantly positive influence on IC. As with ethnicity, gender was also impacted in the study, with gender having a direct influence on long-term retention and IC. Female students demonstrated higher long-term retention independent of IC; however, IC did not mediate how gender influenced long-term retention (z-value = -1.125; p = 0.112). It should be noted that the instructor was both African American and female. To further investigate this finding, follow-up studies are needed where the instructor's gender and ethnicity are treatments in an experimental design. Including IC in the model suggests that ethnicity does not independently impact long-term retention; however, its influence on IC and engagement is important. Prior research found a significant mediating effect as it relates to the instructor's gender and ethnicity (Ehrenberg et al., 1995; Redding, 2019), although this was not found in this study. The relationship between a student's gender and engagement could be partially mediated by the student's perception of IC (Bennett, 1982; Leraas et al., 2018), but this effect was not significant in this study.

Active learning appeared to affect two of the four dependent variables, albeit in differing manners. In the MLM analysis, active learning showed a significant positive effect on LTR and a significant negative effect on STR; however, engagement interacted with the active learning's influence on STR, such that as engagement increased, the relationship between active learning and STR moved from being negative to being positive. Interestingly, time point interacted with active learning's effect on LTR in the opposite direction; over time, active learning's effect on LTR moves from being positive toward being negative. In total, these results reveal how active learning, engagement, short-term retention, and long-term retention are intertwined.

4.6 Summary

The research findings partially supported Hypothesis H1 but none of the other hypotheses. Additionally, the study findings indicate that age, ethnicity, and major have some influence on students' performance and age may have some influence on short-term retention. Although the findings of the study were not proven to be significant, the post hoc MLM testing (Figure 3) discovered areas where future work could be valuable.

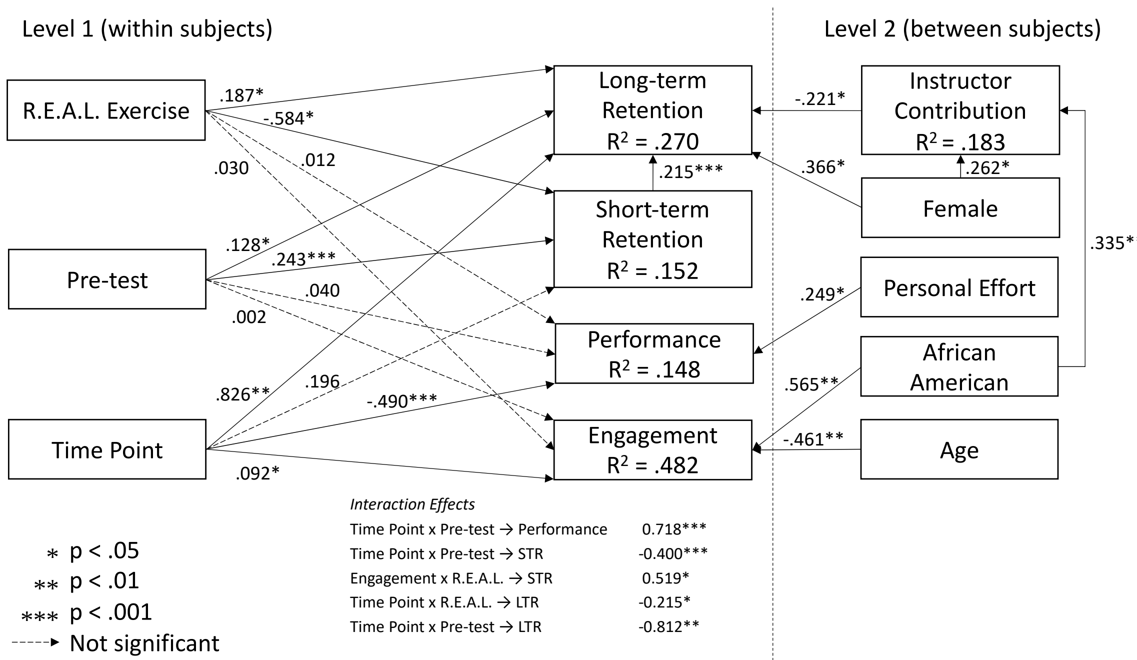

Figure 3. Multilevel Model Showing Relationships Within Subjects and Between Subjects Used in the Study of Treatment Conditions.

CHAPTER V

CONCLUSION

Chapter V presents the conclusion of the study. Coverage of the conclusion is broken into the following: (1) academic contributions; (2) strengths of study; (3) limitations of study; (4) suggestion for future research; and (5) conclusion.

This quasi-experimental study investigated the use of active learning strategies in the form of R.E.A.L. treatments to accompany the traditional lecture-based format in an IS data communication and networking course. For this study, a variety of active learning techniques and strategies were implemented in combination with the traditional lecture-based format in the two course sections using a crossover design where each section received both the R.E.A.L. treatments as well as the traditional lectures. The study's goal was to determine whether the implementation of R.E.A.L. treatments would impact student performance, STR, LTR, and engagement as compared to content delivered via only traditional lectures.

The study produced mixed results. Statistical analysis of the direct effects of R.E.A.L. treatments on student performance, STR, LTR, and engagement failed to fully support any of the four hypotheses. However, post hoc tests of direct effects, interaction effects, and indirect effects using a MLM approach showed some areas for future work in certain demographics, especially gender and ethnicity.

5.1 Academic Contributions

This study provided a contribution to the limited literature on the effect of active learning strategies in IS data communication and networking courses. Research on active learning strategies in computing education had previously focused on programming, project management, database, and other computing courses. This study examined how active learning strategies, R.E.A.L. treatments, used in an IS data communication and networking course impacted student performance, STR, LTR, and engagement. While there is research in higher education computing courses addressing the impact of active learning strategies, there are limited studies on the impact of active learning strategies in an IS data communication and networking course.

Although the study did not produce generalizable results, computing educators can use the findings of this study to examine active learning strategies in an IS data communication and networking class. Based on the post hoc findings in the research, active learning strategies may be effective in certain settings and demographics focusing on gender and ethnicity. Research suggests that same-gender and same-ethnicity instructor roles can impact student performance (Oliver et al., 2021; Opie et al., 2019). Female students were more likely to have better long-term engagement independent of the IC. IC maybe especially important for African American students (Bartman, 2015; Harper, 2007). Including IC in the model suggests that being African American does not independently lead to better long-term retention; it influences long-term retention indirectly through IC.

There is literature to support the post hoc finding on ethnicity. As stated in prior research, the instructor acts as a role model (Dortch & Patel, 2017; Drury et al., 2011; I.

R. Johnson et al., 2019; Solanki & Xu, 2018). The results are consistent with the findings that when a student's ethnicity matches that of the instructor, the instructor, acting as role model, is viewed a contributing to their learning and as a result the student's engagement is higher (Dortch & Patel, 2017; I. R. Johnson et al., 2019).

5.2 Strengths of Study

A major strength of this study lies in the quasi-experimental study design. The design is useful in situations where it is difficult or impossible to implement random assignments (Bhattacherjee, 2012; R. B. Johnson & Christensen, 2019). Additionally, using self-selected groups helps to remove ethical or practical concerns such as requiring someone to belong to a group (Bhattacherjee, 2012; R. B. Johnson & Christensen, 2019). This study used an intact group where the subjects self-selected the IS data communication and networking course. Students signed up for one of the two course sections offered on the same days but at different times by choice. No selection procedure took place, the group of participants was not randomly selected.

Conducting the study in an in-field, authentic, natural setting examines the interventions in a real-world component instead of in an artificial lab environment that may not reflect the real world. (Bhattacherjee, 2012; Creswell & Clark, 2017; R. B. Johnson & Christensen, 2019; McGrath, 1995; Shadish et al., 2002). This type of research, field or applied research, is beneficial because it helps to establish external validity or generalizability and the subjects may behave more naturally and likely to reflect real life (Bhattacherjee, 2012; Creswell & Clark, 2017; R. B. Johnson & Christensen, 2019; McGrath, 1995; Shadish et al., 2002).

The study was strong in realism. The experiment took place using real students self-selecting actual courses required by their major. The assignments and the students' grades on them and on any subsequent assessments, were real and were used as the basis for their course grade.

The use of the crossover method is also a strength of the study. It allows each student to act as his or her own control to decrease the impact of confounding control variables and allow the researchers to compare the effect of multiple treatments (Lui, 2016; Shadish et al., 2002). Each student can act as their own control because they were all exposed to the independent variable at all its levels, lecture accompanied by active learning treatment (R.E.A.L.) and lecture alone. As a result of this comparison, the characteristics of the students exposed to the same levels of the independent variables are the same. No confounding can occur due to the slight differences between the comparison groups. The crossover method also insured each student experienced both types of treatments while receiving any benefits and experiences of both the traditional lecture-based learning and R.E.A.L. treatments (Lui, 2016; Shadish et al., 2002). The crossover design was employed for ethical reasons giving all the students equal exposure to any benefits of the pedagogical innovation and requires a reduction in the number of participants needed for a study than in a randomized design study (Lui, 2016; Shadish et al., 2002).

The repeated measures design provides another strength. A total of eight R.E.A.L. treatments were developed and tested. The results ultimately are not based on the results of a single treatment but on the evaluation of all eight. The repeated measures design allows a smaller number of participants in the study as the same participants are repeatedly used reducing participant variables, but the design ensures that the study participants are equated across treatments since fewer people are necessary and same participants take part in all conditions (Bhattacherjee, 2012; R. B. Johnson & Christensen, 2019). The repeated treatments attempted to foster student exposure to all the levels of the independent variable using the crossover design, ensuring multiple measurements of each subject throughout the semester. All the students participated in four experimental and four control treatments.

Another inherent strength of the study is its longitudinal research design. The study involved collecting data on the same variables repeatedly for the entire semester. The study involved repeated measurements of the same variables at different intervals during the 16-week semester where the dependent variables, student engagement, STR, LTR, and engagement, were measured and compared at several time points for each participant (Bhattacherjee, 2012; R. B. Johnson & Christensen, 2019).

The study used the previously validated ASPECT Survey used for the final class perception survey with one additional open ended question added to the survey (Appendix D). The ASPECT survey was developed to capture student engagement for wide-ranging active-learning strategies normally applied in a college setting (Wiggins et al., 2017). The survey used was an adaptation from the study of Wiggins et al. (2017). An inherent strength of survey research is the survey can capture factual data, like the demographic information, participant feedback after an intervention, or measure participants preferences as done in the ASPECT survey (Bhattacherjee, 2012; R. B. Johnson & Christensen, 2019).

5.3 Limitations of Study

A major limitation of this study is its low generalizability. The study was conducted at a single institution at a regional state-affiliated university. The data sampled came from a single course taught during one semester by one instructor at that instructor's institution and focused on one subject area — IS data communication and networking. The sample size for the study (N = 36) did not consist of a very diverse range of ages, genders, or ethnicities. In addition, the students were not randomly selected for the study. Although the institution has many comparable peer institutions, it may be unique in many ways that could affect the implementation of the repeatability. It cannot be concluded whether the results are transferable to other courses, instructors, subjects, or regional state-affiliated universities.

The crossover method allowed all the students to gain any benefits and experience of both the traditional lecture-based treatment and the R.E.A.L. treatments; however, this may have weakened any impact of the treatment effects. When using a crossover design, the main validity threat is the potential for carryover effects contaminating the second measurement period (Lui, 2016). In this study, there was a possibility for carryover effects contamination which occurs when the performance in one treatment is affected by the participation in a previous treatment (R. B. Johnson & Christensen, 2019; Lui, 2016). The intervention must be able to be washed out and not have carryover effects between study periods (R. B. Johnson & Christensen, 2019; Lui, 2016). In this study, during the design phase, periods of implementation and sequences were created to leave sufficient time between treatments, and also short experimental periods were used to ensure not to have carryover effects.

The self-reported nature of the data by the researcher can be problematic and lead to biased results. The researcher was also the instructor for the course and creator of the R.E.A.L. treatments used in the study as impacting the possibility of research bias as a limitation (Bhattacherjee, 2012; R. B. Johnson & Christensen, 2019). Research bias must always be considered when the instructor studies his or her teaching methods and is a common limitation in constructivist research because the researcher is also usually a collector of the data (Vaughan et al., 2019). The researcher made efforts to minimize this risk by making the surveys anonymous and not analyzing the results until final grades had already been submitted so the students would feel comfortable participating in the study.

There was also a limitation of previous research in the findings. Priori were not hypothesized, meaning the study was not based on earlier research (Bhattacherjee, 2012; R. B. Johnson & Christensen, 2019). As such, they would need to be re-tested in a future study for a more reliable scientific conclusion. Research conducted at a single school, research on a single course, a small, non-diverse sample size, the lack of randomization of students because they self-selected, potential risks associated with using a crossover design, potential risks associated with using self-reported nature of data, potential researcher bias, subset of exam questions were mapped to only one concept and could possibly tested multiple concepts, and a study that was not based on prior research were all limitations of the findings.

5.4 Suggestions for Future Research

Additional research is needed to fully understand the role active learning strategies can play in both an IS data communication and networking course and computing education in general. A valuable future study would be to determine if the findings from the multilevel model are generalizable across various courses, instructors, and institutions. The findings from this study did not support the hypotheses but study concepts could be researched using a different research strategy. Additional questions, better mapping of questions with the treatments, and a cross-sectional field survey design would be ways to achieve this result. The further research could apply the same protocol used in this study to other disciplines in computing, to confirm the findings of this study as well as broaden the application of this teaching method.

Further future research could examine the effectiveness of active learning strategies in different contexts, such as in different geographic locations, different colleges, different instructors, and in different computing subject areas (programming, project management, web design, database, data structures, etc.) to improve the generalization of the research. Studies could also conduct randomized controlled trials of the effects of the R.E.A.L. treatments to remove the within-group differences which is a risk associated with quasi-experiments (R. B. Johnson & Christensen, 2019). A quasi-experimental design does not rely on random subject assignment in order to determine a cause and effect relationship between an independent and dependent variable that may cause a problem within the groups. Additionally, a more complexed, longitudinal study over an entire academic year—fall, spring, and summer semesters could take place where data from different participants over time are collected over time and the same treatments are used (R. B. Johnson & Christensen, 2019).

There are many opportunities for further investigation. Future studies could investigate the impact of active learning strategies in different modalities, such as fully online or hybrid computing courses. It could examine various active learning activities separately through a comparison study to determine which type of active learning strategy works better with which type of activity. Potential research could also examine how different active learning techniques affect the different demographic features of students, including gender, age, ethnicity, first-generation, underrepresented students, those with learning and physical disability, and ESL students. In addition, further research could include adding a qualitative component to the study to provide more open-ended questions to investigate and explore themes regarding students learning styles and active learning activities.

5.5 Conclusion

The use of active learning strategies in an IS data communication and networking course was explored as a supplement to the traditional lecture-based format in this quasi-experimental study. This study sought to determine if the use of active learning strategies impacted student learning outcomes in an IS data communication and networking course by measuring student performance, STR, LTR, and student engagement. Although this research did not yield generalizable results, there is some indication in the post hoc analysis that some of the R.E.A.L. treatments impacted certain demographics of students in the study. Additional research studies are needed to determine if these active learning strategies could be an effective resource for college instructors in IS data communication and networking, and other computing, courses.

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APPENDICES

Appendix A

Examples of Active Learning Strategies

Active Learning Activity	**Description**
One-Minute Papers	A short writing activity, approximately one-minute or less, where the students respond to a question posed by the instructor about a class topic. Created by Charles Schwartz as a classroom assessment technique in the early 1980s (Angelo & Cross, 2012).
Think-Pair-Share	The teacher, as the facilitator, poses a problem or question to the students based on the lecture or reading. Students work together to solve and determine an answer. The student first think about the answer, then the student is paired with another student. The pair share their responses with each other. This technique was developed by Frank Lyman in 1981 (Lyman, 1981).
Gallery Walks	A question or topic is presented on a poster at various stations around the room. Students move from station to station to analyze the information presented. They update the poster with their feedback. This activity promotes interactive discussion among the students (Hickey & Holbrook, 2000).
Games and Crossword Puzzles	Games and crossword puzzles The usage of crossword puzzles and game show-like games help to review material. (Faust & Paulson, 1998)
Concept Maps	A concept map is a visual organization of knowledge showing concepts, ideas, and their relationships. A concept map is created by writing key words and drawing arrows/lines between the ideas showing the relationship. Using the cognitive theory of Ausubel (Ausubel et al., 1968), Novak and Gowin (Novak & Gowin, 1984) created concept maps (Williams, 1995).
Just-In-Time Teaching	Just-in-Time Teaching (JiTT) was developed by Gregor Novak and colleagues to promote active learning in the classroom setting. It relies on a feedback loop between web-based learning materials and the classroom (Novak, 2011; Novak & Gowin, 1984). Students prepare for class by reading provided resources and completing online assignments known as WarmUps that require the students to work outside class. Answers are submitted before class starts, allowing the instructor to determine the level of student understanding and plan the interactive lesson accordingly. (Novak, 2011; Novak & Gowin, 1984).

Note. (Faust & Paulson, 1998; Furse & Ziegenfuss, 2020; Silberman, 1996)

Appendix B

Student Demographic Survey

ID Number: ____

(First two letters of mother's name and the last two numbers of your phone number.)

<u>Pre-Course Survey</u>

Administered to all participants at the beginning of the course.

<u>PERSONAL INFORMATION</u>

1. What is your age? _______

2. What is your gender?
   - ☐ Male
   - ☐ Female
   - ☐ Other

3. What is your race/ethnicity?
   - ☐ African American
   - ☐ Asian American
   - ☐ Asian
   - ☐ Hispanic American
   - ☐ Hispanic
   - ☐ Native American
   - ☐ White/Caucasian

4. What is your major?
   - ☐ Information Systems
   - ☐ Information Technology
   - ☐ Health Informatics
   - ☐ Other: ______________________

5. Have you taken a networking or data communication course before this course? If so, when, and where did you take the course?

   ____

6. How many hours are you taking this semester? _____ hours

7. How many courses are you taking this semester? ____courses

8. How many hours per week do you work? __________

9. Do you have a computing internship?
   - ☐ Yes, If so, with what organization/company? ______________________________
   - ☐ No

10. Do you work or have your ever worked in the computing field?
   - ☐ Yes, If so, please state your title and the organization. _____________________
   - ☐ No

11. What other commitments do you have to balance with out-of-class work for this course?
   (For example: military reserve, family, service organizations, etc.) ________________
   ____

12. Do you own, or do you plan to purchase the textbook for the course?
   - ☐ Yes
   - ☐ No If no, why? ____

13. What is your estimated overall GPA? _______

14. What is your estimated major GPA? _______

15. What is your expected grade in this course? _______

16. What is your lowest acceptable grade for this course? _______

<u>CURRICULUM CHOICE</u>

17. What are the top three (3) significant influences on choosing a computing career?
   - ☐ Science/math aptitude
   - ☐ Interest in field
   - ☐ Mobility/employment opportunities in many locations
   - ☐ Pay
   - ☐ Solving socially important problems
   - ☐ A role model/positive experience
   - ☐ Family member
   - ☐ Career day/open house
   - ☐ High school advisor
   - ☐ Friend/classmate
   - ☐ Summer program
   - ☐ Other

18. What is your certainty regarding your choice in a computing career?
   - ☐ Easy choice
   - ☐ Tough choice, but convinced it is the right choice
   - ☐ Still not sure

19. What is your knowledge of what type of work IS/IT professionals do after graduation?

- ☐ Detailed
- ☐ Fairly good idea
- ☐ Some idea
- ☐ Almost no idea

20. Rate your confidence in your networking knowledge abilities on a scale of 1-10, with 1 being the lowest and 10 being the highest.

○	○	○	○	○	○	○	○	○	○
1	2	3	4	5	6	7	8	9	10
Lowest									Highest

21. Please explain your rating in the previous question. ___________________________

____

Thank you for your input.

Appendix C

Student Engagement Survey

1. The exercise/lecture was engaging.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

2. The _________ increased my understanding of __________ concepts.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

3. The exercise/lecture helped me learn _______ concepts.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

4. The exercise/lecture was a good way to review class material for the exam.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

5. The exercise/lecture was NOT relevant to the course.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

Appendix D

Unit Exams Subset Questions Mappings to STR and LTR

Unit Exam: Single Networks

Variable	R.E.A.L. Treatment
STR01 Transport v. Internet Layer	R.E.A.L. Exercise #2 Single Networks
STR02 Switches/Frames	R.E.A.L. Exercise #2 Single Networks
STR03 Conversion Hexadecimal	R.E.A.L. Exercise #1 Single Networks
STR04 Conversion Binary-Decimal	R.E.A.L. Exercise #1 Single Networks
STR05 EUI-48	R.E.A.L. Exercise #1 Single Networks
STR06 LAN	R.E.A.L. Exercise #1 Single Networks
STR07 802.3	R.E.A.L. Exercise #2 Single Networks
STR08 Modified OSI Model-Layers	R.E.A.L. Exercise #2 Single Networks
STR09 3-way Handshake	R.E.A.L. Exercise #2 Single Networks
STR10 What is an internet?	R.E.A.L. Exercise #1 Single Networks

Unit Exam: Wireless

Variable	R.E.A.L. Treatment
STR01 2.4 v. 5 GHz	R.E.A.L. Exercise #3 Wireless Networks
STR02 Cell phone Antenna	R.E.A.L. Exercise #3 Wireless Networks
STR03 Channel Interference	R.E.A.L. Exercise #3 Wireless Networks
STR04 I.T. staff working on college network	R.E.A.L. Exercise #3 Wireless Networks
STR05 Channel	R.E.A.L. Exercise #3 Wireless Networks
STR06 Roque Access Point	R.E.A.L. Exercise #3 Wireless Networks
STR07 Access Point Role	R.E.A.L. Exercise #3 Wireless Networks
STR08 Tips for wireless network	R.E.A.L. Exercise #3 Wireless Networks
STR09 Bluetooth	R.E.A.L. Exercise #4 Wireless Networks
STR10 Five wireless propagation issues	R.E.A.L. Exercise #3 Wireless Networks

Unit Exam: TCP/IP

Variable	R.E.A.L. Treatment
STR01 LAN	R.E.A.L. Exercise #5 TCP/IP
STR02 Three steps of routing	R.E.A.L. Exercise #6 TCP/IP
STR03 Types of routers	R.E.A.L. Exercise #6 TCP/IP
STR04 NAT	R.E.A.L. Exercise #6 TCP/IP
STR05 Leased lines	R.E.A.L. Exercise #6 TCP/IP
STR06 Switching v. Routing	R.E.A.L. Exercise #5 TCP/IP
STR07 Network admin makes decision	R.E.A.L. Exercise #6 TCP/IP
STR08 Mask	R.E.A.L. Exercise #5 TCP/IP
STR09 ADSL v. Cable	R.E.A.L. Exercise #6 TCP/IP
STR10 LAN MAN WAN	R.E.A.L. Exercise #5 TCP/IP

Unit Exam: Networked Applications and Security

Variable	R.E.A.L. Treatment
STR01 Hacker	R.E.A.L. Exercise #7 Networked Applications Security
STR02 Spear phishing	R.E.A.L. Exercise #6 Networked Applications Security
STR03 Worms v. Viruses	R.E.A.L. Exercise #6 Networked Applications Security
STR04 Hacking	R.E.A.L. Exercise #7 Networked Applications Security
STR05 Ping	R.E.A.L. Exercise #6 Networked Applications Security
STR06 Malware	R.E.A.L. Exercise #7 Networked Applications Security
STR07 Hackers	R.E.A.L. Exercise #7 Networked Applications Security
STR08 Network Command Line	R.E.A.L. Exercise #6 Networked Applications Security
STR09 Rated speed	R.E.A.L. Exercise #6 Networked Applications Security
STR10 Hacking or not hacking	R.E.A.L. Exercise #7 Networked Applications Security

Appendix E

Subset Final Exam Questions Mappings to STR and LTR

Comprehensive Final Exam

Variable	**R.E.A.L. Treatment**
LTR_Q1 users-application level	R.E.A.L. Exercise #7 Networked Applications Security
LTR_Q2 wireless LAN	R.E.A.L. Exercise #3 Wireless Networks
LTR_Q3 3-way handshake	R.E.A.L. Exercise #2 Single Networks
LTR_Q4 well-known ports	R.E.A.L. Exercise #6 TCP/IP
LTR_Q5 throughput v. rated speed	R.E.A.L. Exercise #5 TCP/IP
LTR_Q6 most serious propagation	R.E.A.L. Exercise #3 Wireless Networks
LTR_Q7 Ethernet-hierarchical	R.E.A.L. Exercise #1 Single Networks
LTR_Q8 Satellite	R.E.A.L. Exercise #3 Wireless Networks
LTR_Q9 EUI-48	R.E.A.L. Exercise #1 Single Networks
LTR_Q10 Router	R.E.A.L. Exercise #5 TCP/IP
LTR_Q11 PAN	R.E.A.L. Exercise #4 Wireless Networks
LTR_Q12 Hacking	R.E.A.L. Exercise #7 Networked Applications Security
LTR_Q13 WLAN	R.E.A.L. Exercise #3 Wireless Networks
LTR_Q14 Malware	R.E.A.L. Exercise #7 Networked Applications Security
LTR_Q15 VPN	R.E.A.L. Exercise #8 Networked Applications Security
LTR_Q16 What is the Internet?	R.E.A.L. Exercise #1 Single Networks
LTR_Q17 conversion binary-decimal	R.E.A.L. Exercise #1 Single Networks
LTR_Q18 What is a network?	R.E.A.L. Exercise #1 Single Networks
LTR_Q19 Rated Speed	R.E.A.L. Exercise #5 TCP/IP
LTR_Q20 Modified OSI model-layers	R.E.A.L. Exercise #6 TCP/IP

Appendix F

Final Class Perception of Active Learning Activities

ID Number ____

Final Class Perception of Active Learning Activities

1. The active learning activities/exercises during class stimulate my interest in the data communication and networking topics.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

2. I am confident in my understanding of the material presented during the active learning portions of the class sessions.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

3. I would prefer to take a class that involves active learning activities/exercises over one that does not.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

4. Overall, the other members of the group make valuable contributions during the active learning activities/exercises.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

5. I had fun doing the active learning activities/exercises sessions.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

6. Group discussion during the activity contributes to my understanding of the course material.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

7. Having the material explained to me by group members improves my understanding of the material.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

8. Explaining the material to my group improved my understanding of it.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

9. The active learning exercises/activity increased my understanding of the course material.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

10. I work hard during active learning activity/exercise sessions.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

11. I am focused during active learning activity/exercise sessions.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

12. I make a valuable contribution to my active learning activity/exercise group session.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

13. The instructor is available to answer questions during the active learning activity/exercise session.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

14. The instructor seems prepared for the active learning activity/exercise session.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

15. The instructor puts a good deal of effort into my learning for the class.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

16. The instructor's enthusiasm made me more interested in the active learning session.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

17. Below please add any additional comments about the value of the active learning activities/exercises, the course in general, or your preferred style of instruction.

Appendix G

R.E.A.L. Treatments

R.E.A.L. Exercise #1 Description

(Group A & B)

Course Unit	Single Networks
R.E.A.L. Exercise Name	Welcome to the CIS 321 Help Desk
Prerequisite Knowledge	Before doing this exercise, the student should have: 1. Read Chapters 1, 2, and 5. 2. Completed online quizzes for Chapters 1, 2, and 5.
Learning Outcomes	Upon completion of this module, the student should be able to meet the following ABET and course learning outcomes: • ABET (Analysis) • Explain basic networking concepts, terminology, and theory
Keywords	Host, Server, Network
Duration	10-15 minutes (one minute paper) end of lecture and discussion
Exercise	Explain the concept of a network and basic components
Instructions	You have just been hired as a new intern for a company that has started a new computer help desk. The help desk offers a variety of services ranging from troubleshooting and support via the phone/email/text to hands-on hardware repair. To qualify for the position, you must be able to service, troubleshoot, and fix problems on the network. Strong problem solving and communication skills are essential to be a success as a help desk professional. Answering questions in a timely manner is also an important part of working at the help desk. Many times, you have to give a rapid fire response. One of your customers has just called and needs you to answer the following questions: 1. What is a network? 2. What is a host? 3. What is a server? 4. How do networks help us? 5. Draw a picture of a network.

R.E.A.L. Exercise #2 Description

(Group A Only)

Course Unit	Single Networks
R.E.A.L. Exercise Name	Hello!
Prerequisite Knowledge	Before doing this exercise, the student should have: 1. Read Chapters 1, 2, and 5. 2. Completed online quizzes for Chapters 1, 2, and 5.
Learning Outcomes	Upon completion of this module, the student should be able to meet the following ABET and course learning outcomes: • ABET (Analysis) • Explain message ordering for TCP three-step opening • Explain message ordering for TCP four-step closing
Keywords	TCP, ACK, SYN, FIN
Duration	15-20 minutes (strip sequence)
Exercise	The students will be divided into groups of four. Each group will be given strips of paper with the three steps for a TCP three-step opening and strips of paper with the four steps for a TCP four-step closing. The students will be asked to work together to reconstruct the proper sequence for each handshake and tape to a piece of cardboard. Group members are called on to share their answers and summarize the exercise. Students are asked to answer the following questions during the exercise: 1. Which host initiates the communication? 2. Why are sequence numbers important? 3. What is SYN? ACK? SYN/ACK? FIN? 4. TCP is a connection-oriented protocol. What does this mean? 5. Why is TCP a reliable protocol?

R.E.A.L. Exercise #3 Description

(Group B Only)

Course Unit	Wireless Networks
R.E.A.L. Exercise Name	How secure is your wireless network?
Prerequisite Knowledge	Before doing this exercise, the student should have: 1. Read Chapters 6 and 7 2. Completed online quizzes for Chapters 6 and 7
Learning Outcomes	Upon completion of this module, the student should be able to meet the following ABET and course learning outcomes: • ABET (Analysis) • Explain the components of a wireless network • Demonstrate how to connect to a wireless network
Keywords	802.11, Wi-Fi, Wireless
Duration	10 minutes (Think Pair Share) compared several different devices (smart phones, tablets, and laptops)
Exercise	Wireless has become as essential in our daily lives as electricity. Wireless is available at home, work and even in our cars. You are working as a student ambassador at an event. Everyone is arriving and wants to connect to the free Wireless network named Open. Walk your visitors to campus on how to connect to the school's Wi-Fi. Remember that you have all ranges of users. • Go to settings and enable Wi-Fi on your smart phone or tablet. • Select the Open wireless network to see what other devices are in the area. Answer the following customer questions 1. Name two other Wi-Fi networks available. 2. How can you tell if the Wi-Fi is password protected? 3. Are all public Wi-Fi safe? 4. Name some ways you can protect your device from being hacked. 5. Name some precautions you can take to protect your home wireless network.

R.E.A.L. Exercise #4 Description

(Group A Only)

Course Unit	Wireless Networks
R.E.A.L. Exercise Name	Bluetooth
Prerequisite Knowledge	Before doing this exercise, the student should have: 1. Read Chapters 6 and 7 2. Completed online quizzes for Chapters 6 and 7
Learning Outcomes	Upon completion of this module, the student should be able to meet the following ABET and course learning outcomes: • ABET (Analysis) • Explain Bluetooth local wireless technologies • Demonstrate how to connect via Bluetooth technologies
Keywords	Bluetooth, Internet of Things (IoT) devices, PANs
Duration	(Think Pair Share)10-15 minutes before the end of class
Exercise	Everyone is in line at the huge electronic sale for the latest gadgets that technology has to offer at the Geek Store. You are working part time at the Geek Store. The customers have a lot of technique questions. Many of the devices on sale has the following symbol on the label . This is the symbol that represents Bluetooth. • Go to settings and enable Bluetooth on your smart phone or tablet. • Select Bluetooth to see what other devices are in the area. Bluetooth is a wireless communications technology that does automatically discover and communicate with new devices that come within range. Answer the following customer questions 1. Name three devices that use Bluetooth technology. 2. What is the difference between Bluetooth LE and Bluetooth Classic? 3. How do you set a password on Bluetooth devices? 4. Name four disadvantages of using Bluetooth. 5. What is a PAN?

R.E.A.L. Exercise #5 Description

(Group B Only)

Course Unit	TCP/IP
R.E.A.L. Exercise Name	What’s your speed? Rated Speed vs. Throughput
Prerequisite Knowledge	Before doing this exercise, the student should have: 1. Read Chapters 8, 9, 10 2. Completed online quizzes for Chapters 8, 9, 10 3. Read p. 219 of the textbook
Learning Outcomes	Upon completion of this module, the student should be able to meet the following ABET and course learning outcomes: • ABET Analysis • Demonstrate how to do a speed test • Demonstrate the difference between wired and wireless networks • Discuss factors impact network speed and throughput
Keywords	Rated speed, Throughput
Duration	10 minutes (compared several laptops and location in the room)
Exercise	Rated speed is the official speed of the technology. It is the speed that is advertised on the commercials to the customer. Throughput is the transmission speed that users actually get. And usually, the throughput is lower than a transmission system’s rated speed. Check the speed of the open wireless network. 1. Go to speedtest.net. 2. Click on Go. 3. Screenshot and copy the results to Word. 4. Record the following (information that the speed test gives you): • Ping • Download Speed • Upload Speed • IP Address • Service Provider • Server Name and Location 1. Is the rated speed and the throughput the same? 2. Why are you not getting the rated speed? 3. Repeat the exercise two more times from other locations within the room or the hallway. What do you notice about all three speed test captures?

Note. (Panko & Panko, 2019)

R.E.A.L. Exercise #6 Description

(Group A Only)

Course Unit	TCP/IP
R.E.A.L. Exercise Name	Wireshark
Prerequisite Knowledge	Before doing this exercise, the student should have: 1. Read Chapters 8, 9, 10 2. Completed online quizzes for Chapters 8, 9, 10 3. Read p. 286-291 of the textbook
Learning Outcomes	Upon completion of this module, the student should be able to meet the following ABET and course learning outcomes: • Analysis and Development • Explain and demonstrate a network protocol analyzer
Keywords	Handshake, Sockets, SYN, ACK, FIN, RST
Duration	20-30 minutes
Exercise	You have been hired at a local IT firm and one of your job duties is to monitor and look at individual packets on the network. Packet capture programs are used to record packets entering and exiting the computer. In order to do this exercise, you must capture a webserver interaction. This will allow you to review the header fields, TCP 3-way handshake connection, and several other items that has been covered this semester. 1. Download Wireshark 2. Start Wireshark 3. Turn on Wireshark Capture 4. Type a URL in your browser window 5. After a few seconds, stop the capture. See handout and pages 286-291 for detailed directions and how-to pictures. 1. What URL did you use? What was the IP address of the webserver? 2. Find the frame in which your PC sent the SYN packet. List the source and destination IP address, the source and destination port numbers, and the header checksum. 3. Select the SYN/ACK packet. List the source and destination IP address, the source and destination port numbers, and the header checksum. 4. Select the packet that acknowledges the SYN/ACK segment. List the source and destination IP address, the source and destination port numbers, and the header checksum.

Note. (Panko & Panko, 2019)

R.E.A.L. Exercise #7 Description

(Group B Only)

Course Unit	Networked Applications and Security
R.E.A.L. Exercise Name	Cell Phone Risk Assessment
Prerequisite Knowledge	Before doing this exercise, the student should have: 1. Read Chapters 11, 3, 4 and pages 392-393 of the textbook 2. Completed online quizzes for Chapters 11, 3, and 4
Learning Outcomes	Upon completion of this module, the student should be able to meet the following ABET and course learning outcomes: • ABET-Analysis, Development, and Teamwork
Keywords	Apps, Identify Theft, Credit Card Theft, Root Privileges
Duration	20-30 minutes
Exercise	The purpose of this exercise is for the students to identify and discuss smartphone apps that they have on their devices. The teams make a list of the most used apps on their smartphones, then discuss in detail the specific applicable threats caused if the device app is compromised. 1. List the top five (5) apps that you used the most on your smartphone. 2. Does the app have any unique identity information stored about you in the app? 3. If the app was compromised, what kind of data would be at risk? 4. If the app was compromised, what kind of identity data would be at risk? 5. Rank the most risked apps in order from the most risky to the least risky if it was compromised.

Note. (Panko & Panko, 2019)

R.E.A.L. Exercise #8 Description

Group A & B

Course Unit	Networked Applications and Security
R.E.A.L. Exercise Name	Crossword Puzzle
Prerequisite Knowledge	Before doing this exercise, the student should have: 1. Read Chapters 1-11 2. Completed online quizzes for Chapters 1-11 3. Completed all unit exams covering Chapters 1-11 4. Completed all in-class assignments 5. Completed the research paper assignment
Learning Outcomes	Upon completion of this module, the student should be able to meet the following ABET and course learning outcomes: • ABET-Analysis, Development, Communication, Ethics and Teamwork • All of the student learning objectives listed on the course syllabus
Keywords	Crossword Puzzle, Comprehensive Final Exam, Basic Networking Terms
Duration	20 minutes for team collaboration 30 minutes review of correct answers and discussion
Exercise	Work as a team to complete the crossword puzzle. Use the four job IT/IS/HI/CS job descriptions as a word bank to complete the crossword to review key terms and concepts that you need to know for the final exam.

Note. (Whisenand &Dunphy 2010)

Appendix H

Institutional Review Board Approval Letter

irb@southalabama.edu

UNIVERSITY OF SOUTH ALABAMA

TELEPHONE: (251) 460-6308
CSAB 138 · MOBILE, AL. 36688-0002

INSTITUTIONAL REVIEW BOARD
August 10, 2018

Principal Investigator:	Rhonda Lucas, M.S.		
IRB # and Title:	IRB PROTOCOL: 18-245 [1282153-1] The Effects of Real-World Experiences in Active Learning (R.E.A.L.) in a Data Communications and Networking Course		
Status:	APPROVED	Review Type:	Expedited Review
Approval Date:	August 8, 2018	Submission Type:	New Project
Initial Approval:	August 8, 2018	Expiration Date:	August 7, 2019
Review Category:	Category: 45 CFR 46.110 (7): Research on individual or group characteristics or behavior		

This panel, operating under the authority of the DHHS Office for Human Research and Protection, assurance number FWA 00001602, and IRB Database #00000286, has reviewed the submitted materials for the following:

1. *Protection of the rights and the welfare of human subjects involved.*
2. *The methods used to secure and the appropriateness of informed consent.*
3. *The risk and potential benefits to the subject.*

The regulations require that the investigator not initiate any changes in the research without prior IRB approval, except where necessary to eliminate immediate hazards to the human subjects, and that **all problems involving risks and adverse events be reported to the IRB immediately!**

Subsequent supporting documents that have been approved will be stamped with an IRB approval and expiration date (if applicable) on every page. Copies of the supporting documents must be utilized with the current IRB approval stamp unless consent has been waived.

Notes:

irb@southalabama.edu

UNIVERSITY OF SOUTH ALABAMA

TELEPHONE: (251) 460-6308
AD 240 · MOBILE, AL. 36688-0002

INSTITUTIONAL REVIEW BOARD
August 19, 2019

IRB Number and Title:	[1282153-2] The Effects of Real-World Experiences in Active Learning (R.E.A.L.) in a Data Communications and Networking Course
Reference Number:	18-245
Principal Investigator:	Rhonda Lucas, M.S.
Next Report Due Date:	August 13, 2020

This project has transitioned to the HHS Final Rule dated July 19, 2018, provision 2) The allowance for no annual continuing review of certain categories of research

The annual Check-In has been completed to notify the IRB that the research remains ongoing. Stamped study related materials have been updated to remove the date of expiration

An annual notification will be automatically generated through IRBNet 60 and 30 days prior to the next Check-In. Failure to submit the annual Check-In form will result in the project being closed.

Appendix I

Informed Consent to Participate in Research Study

Title of Project: The Effects of Real-World Experiences in Active Learning (R.E.A.L.) in a Data Communication and Networking Course

Principal Investigators: Rhonda Lucas (rhondalucas@southalabama.edu)
Dr. Sue Mattson (smattson@southalabama.edu)

Purpose: You are invited to participate in a research study comparing two methods of teaching Data Communication and Networking (CIS 321). By conducting this study, I hope to improve the way I teach CIS 321 here at USA.

How Participants Will Be Selected: All students enrolled in Data Communication and Networking (CIS 321) in Fall 2019 or Spring 2020 are invited to participate in this study.

Procedures: The study will start with one survey administered at the beginning of the course to collect student information including age, gender, race/ethnicity, major, number of hours and classes you are taking, number of hours worked/week, internship and job status, whether you purchased a textbook, GPA, predicted grade, acceptable grade, course goals, expectations, confidence in the field, and subject matter interest. The survey should take no more than 5 minutes of your time. After final grades are submitted, your exam scores will be combined with survey data and your identity will be removed.

Risks: To the best of my knowledge, there is no risk of any kind to student participants.

Potential Benefits: There will be no personal benefit from your participation, but the information gained by doing this research may help improve teaching and learning in this course.

Alternatives to Participation: You do not have to participate in this study. Participation or non-participation in this study will not affect your grade, and your instructor will not be able to determine who participated.

Confidentiality: For the survey, your will provide a code consisting of the first and second letter of your mother's name and the last two digits of your phone number. Dr. Mattson will collect the surveys and create a separate data key to protect confidentiality. The surveys will be stored in a locked cabinet in the office of Dr. Mattson until after grades are posted. After final grades are posted at the end of the semester, Dr. Mattson will correlate your survey responses with your exam data. **Identifying information that connect the survey with exam results will then be deleted.** Ms. Lucas will never be able to identify you from the survey data.

Voluntary Participation: Your participation in this research study is completely voluntary. You do not have to participate.

Contacts and Questions: For questions about your rights as a research participant in this study or to discuss other study-related concerns or complaints with someone who is not a part of the research team, you may contact the Institutional Review Board at 251-460-6308 or email irb@southalabama.edu

You have read, or have had read to you, and understand the purpose and procedures of this research. You have had an opportunity to ask questions which have been answered to your satisfaction. You voluntarily agree to participate in this research as described.

____

Participant Name (printed)/ Signature of Participant Date

____

Signature of Person Obtaining Informed Consent Date

Appendix J

Statistical Analysis for Control Variables

Hypothesis	Treatment	Control Variable	*F*-statistic	*p*-value
Hypothesis 1: Student Performance				
	H1a: Network	Age	0.726	0.401
	H1b: Handshake	Age	0.110	0.742
	H1c: Wireless	Age	12.819	0.001
	H1d: Bluetooth	Age	1.115	0.300
	H1e: Network speed	Age	0.032	0.858
	H1f: Network management	Age	3.908	0.058
	H1g: Types of attacks	Age	0.465	0.501
	H1h: Hacking	Age	3.954	0.057
	H1a: Network	Ethnicity	0.672	0.419
	H1b: Handshake	Ethnicity	5.891	0.022
	H1c: Wireless	Ethnicity	5.566	0.026
	H1d: Bluetooth	Ethnicity	0.016	0.900
	H1e: Network speed	Ethnicity	0.015	0.905
	H1f: Network management	Ethnicity	1.004	0.325
	H1g: Types of attacks	Ethnicity	0.026	0.874
	H1h: Hacking	Ethnicity	0.165	0.687
	H1a: Network	Major	0.488	0.491
	H1b: Handshake	Major	0.370	0.548
	H1c: Wireless	Major	6.313	0.018
	H1d: Bluetooth	Major	0.581	0.452
	H1e: Network speed	Major	1.089	0.306
	H1f: Network management	Major	0.002	0.962
	H1g: Types of attacks	Major	0.195	0.663
	H1h: Hacking	Major	0.462	0.502
	H1a: Network	Gender	0.695	0.412
	H1b: Handshake	Gender	3.880	0.059
	H1c: Wireless	Gender	0.015	0.902
	H1d: Bluetooth	Gender	0.543	0.467
	H1e: Network speed	Gender	0.768	0.388
	H1f: Network management	Gender	0.146	0.705
	H1g: Types of attacks	Gender	1.278	0.268

	H1h: Hacking	Gender	0.025	0.875
Hypothesis 2: Short Term Retention				
	H2a: Network	Age	1.627	0.212
	H2b: Handshake	Age	0.044	0.834
	H2c: Wireless	Age	0.334	0.568
	H2d: Bluetooth	Age	0.976	0.331
	H2e: Network speed	Age	5.709	0.024
	H2f: Network management	Age	5.654	0.024
	H2g: Types of attacks	Age	1.948	0.173
	H2h: Hacking	Age	0.201	0.657
	H2a: Network	Ethnicity	0.024	0.878
	H2b: Handshake	Ethnicity	0.003	0.956
	H2c: Wireless	Ethnicity	2.448	0.129
	H2d: Bluetooth	Ethnicity	0.184	0.671
	H2e: Network speed	Ethnicity	0.958	0.336
	H2f: Network management	Ethnicity	2.684	0.112
	H2g: Types of attacks	Ethnicity	3.207	0.084
	H2h: Hacking	Ethnicity	0.661	0.423
	H2a: Network	Major	0.247	0.623
	H2b: Handshake	Major	0.227	0.638
	H2c: Wireless	Major	0.004	0.948
	H2d: Bluetooth	Major	0.292	0.593
	H2e: Network speed	Major	0.877	0.357
	H2f: Network management	Major	2.862	0.101
	H2g: Types of attacks	Major	0.214	0.647
	H2h: Hacking	Major	0.517	0.478
	H2a: Network	Gender	0.000	0.988
	H2b: Handshake	Gender	1.454	0.238
	H2c: Wireless	Gender	0.189	0.667
	H2d: Bluetooth	Gender	0.070	0.794
	H2e: Network speed	Gender	0.705	0.408
	H2f: Network management	Gender	0.274	0.604
	H2g: Types of attacks	Gender	0.382	0.541
	H2h: Hacking	Gender	0.039	0.845
Hypothesis 3: Long Term Retention				
	H3a: Network	Age	0.178	0.676
	H3b: Handshake	Age	0.182	0.673
	H3c: Wireless	Age	0.474	0.497
	H3d: Bluetooth	Age	0.003	0.960

	H3e: Network speed	Age	1.243	0.274
	H3f: Network management	Age	0.196	0.661
	H3g: Types of attacks	Age	0.248	0.622
	H3h: Hacking	Age	0.324	0.573
	H3a: Network	Ethnicity	0.000	0.999
	H3b: Handshake	Ethnicity	0.085	0.773
	H3c: Wireless	Ethnicity	0.035	0.853
	H3d: Bluetooth	Ethnicity	0.163	0.689
	H3e: Network speed	Ethnicity	1.132	0.296
	H3f: Network management	Ethnicity	0.006	0.938
	H3g: Types of attacks	Ethnicity	0.576	0.454
	H3h: Hacking	Ethnicity	0.187	0.669
	H3a: Network	Major	0.502	0.484
	H3b: Handshake	Major	0.193	0.664
	H3c: Wireless	Major	0.259	0.615
	H3d: Bluetooth	Major	1.192	0.284
	H3e: Network speed	Major	0.012	0.912
	H3f: Network management	Major	0.253	0.619
	H3g: Types of attacks	Major	0.074	0.788
	H3h: Hacking	Major	0.061	0.807
	H3a: Network	Gender	0.004	0.953
	H3b: Handshake	Gender	0.472	0.498
	H3c: Wireless	Gender	0.324	0.574
	H3d: Bluetooth	Gender	1.366	0.252
	H3e: Network speed	Gender	0.011	0.917
	H3f: Network management	Gender	2.406	0.132
	H3g: Types of attacks	Gender	0.888	0.354
	H3h: Hacking	Gender	0.213	0.648
Hypothesis 4: Student Engagement				
	H4a: Network	Age	0.127	*0.724*
	H4b: Handshake	Age	2.131	0.155
	H4c: Wireless	Age	2.184	0.150
	H4d: Bluetooth	Age	3.768	0.062
	H4e: Network speed	Age	0.056	0.815
	H4f: Network management	Age	2.573	0.120
	H4g: Types of attacks	Age	2.455	0.128
	H4h: Hacking	Age	1.174	0.288
	H4a: Network	Ethnicity	0.050	0.824
	H4b: Handshake	Ethnicity	0.118	0.734

	H4c: Wireless	Ethnicity	1.390	0.248
	H4d: Bluetooth	Ethnicity	2.325	0.138
	H4e: Network speed	Ethnicity	0.429	0.518
	H4f: Network management	Ethnicity	1.966	0.171
	H4g: Types of attacks	Ethnicity	3.707	0.064
	H4h: Hacking	Ethnicity	2.086	0.159
	H4a: Network	Major	0.358	0.554
	H4b: Handshake	Major	0.044	0.834
	H4c: Wireless	Major	0.910	0.348
	H4d: Bluetooth	Major	0.046	0.832
	H4e: Network speed	Major	0.145	0.707
	H4f: Network management	Major	0.170	0.683
	H4g: Types of attacks	Major	1.675	0.206
	H4h: Hacking	Major	0.003	0.954
	H4a: Network	Gender	0.943	0.340
	H4b: Handshake	Gender	0.728	0.401
	H4c: Wireless	Gender	0.572	0.456
	H4d: Bluetooth	Gender	0.043	0.837
	H4e: Network speed	Gender	0.112	0.740
	H4f: Network management	Gender	0.003	0.958
	H4g: Types of attacks	Gender	0.006	0.940
	H4h: Hacking	Gender	1.710	0.201

Appendix K

Within-subjects (Level 1) Inter-construct Correlations

Table 14. Within-subjects (Level 1) Inter-construct Correlations Results

Within-subjects (Level 1) Inter-construct Correlations										
	Performance	STR	LTR	Engagement	Treatment	Timepoint	Pre-test x Time Point	Pre-test	Treatment x Engagement	Treatment x Time Point
Performance	---									
STR	0.000	---								
LTR	0.091	0.251	---							
Engagement	0.061	-0.035	0.036	---						
Treatment	-0.024	-0.103	0.013	0.049	---					
Timepoint	0.119	-0.296	-0.020	0.099	-0.013	---				
Pre-test x Time Point	0.293	-0.203	-0.042	0.082	-0.071	0.861	---			
Pre-test	0.323	0.165	0.018	0.003	-0.169	0.114	0.521	---		
Treatment x Engagement	-0.021	-0.084	0.020	0.049	0.983	-0.007	-0.062	-0.148	---	
Treatment x Time Point	0.025	-0.187	-0.029	0.081	0.811	0.401	0.291	-0.045	0.802	---

Appendix L

Between-subjects (Level 2) Inter-construct Correlations

Table 15. Between-subjects (Level 2) Inter-construct Correlations Results

Between-subjects (Level 2) Inter-Construct Correlations								
	African American	Age	Engagement	Female	IC	LTR	PE	Performance
African American	---							
Age	0.194	---						
Engagement	0.132	-0.128	(0.877)					
Female	-0.089	-0.121	0.012	---				
IC	0.350	-0.154	0.079	0.270	(0.893)			
LTR	-0.022	-0.017	0.079	0.036	0.003	---		
PE	0.093	-0.193	0.069	0.035	0.482	0.019	(0.893)	
Performance	-0.089	-0.170	0.061	0.189	0.105	0.026	0.133	---
STR	-0.013	-0.093	0.021	0.052	0.041	0.251	0.035	0.062

Appendix M

Student Answers to Open Ended Question (Question #17)

- Ms. Lucas has been the best teacher I have had since I have been a student here. Her learning exercises helped simplify complex concepts that she helped by allowing me to visualize it in order to get a better understanding. She is very passionate about her work and her students, and I hope I have more instructors like her.

- I enjoyed the hands-on activities done in class.

- Loved this class, you are a great teacher! Keep it up! God Bless :)

- Think overall it was a good course. I just wasn't able to put the time in due to other classes using so other time along with how due dates were set up.

- I generally prefer hands-on learning. Active learning exercises definitely helped me understand concepts.

- I liked "board-days" and whenever we had worksheets. PowerPoints are fine, but they are not my favorite.

- I think you should permanently add these activities/exercises to your teach[ing] style of this class.

- I really enjoyed the class and the way it was instructed.

- Ms. Lucas, you were a wonderful instructor. You knew how to get everyone involved with what's going on in our classroom that deals with the real world, and you care about us. Thank you.

- I'm a hands-on type of learner, so the inclusion of fun activities was a huge help in memorizing harder concepts.

- Mrs. LuLu is super cool.

BIOGRAPHICAL SKETCH

BIOGRAPHICAL SKETCH

Name of Author: Rhonda Luvenia Lucas

Graduate and Undergraduate Schools Attended:

University of South Alabama, Mobile, Alabama

Degrees Awarded:

Doctor of Philosophy in Computing, 2023, Mobile, Alabama
Master of Science in Computer and Information Science, 1998, Mobile, Alabama
Bachelor of Science in Management Information Systems, 1993, Mobile, Alabama

Awards and Honors:

Delta Mu Delta, Business Honor Society
Sigma Beta Delta, Business Honor Society
Upsilon Pi Epsilon, Computing and Information Honor Society
Active Learning Initiative at South Alabama (ALISA) Grant Recipient
Alabama STEM Explorers Contributor-Alabama Public Television
Beth and Don Davis National Alumni Association Advising Award
Excellence in First Year Experience Teacher Award
National Society of Leadership and Success Teaching Award
School of Computing Advisor of the Year
School of Computing Outstanding Teacher of the Year
Yale Center for Teaching and Learning Scientific Teaching Fellow