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The Impact of Intelligent Tutoring Software on Geometry Students

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THE IMPACT OF INTELLIGENT TUTORING SOFTWARE ON GEOMETRY STUDENTS

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DEDICATION

To my husband Danny, for his unconditional love, for believing in me, and for inspiring me to dream. Your strength fascinates me and your heart amazes me. Thank you for loving me throughout endless hours of researching, writing, reading, and for buying me chocolate covered coffee beans when the struggle was real. I would never be who I am in life without you, and I love walking beside you in this beautiful road.

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ABSTRACT

This purpose of this paper is to deepen the understanding for a problem of practice in the mathematics educators' classroom of low retention of information thus leading to poor mathematics achievement. The identification of the problem of practice led to a development of a research focus examining the effects of using intelligent tutoring software in the mathematics classroom and the impact it has on mathematics achievement, student motivation as it relates to self-efficacy, student engagement and attitudes towards mathematics. Using a convergent mixed methods approach (Creswell, 2012), this paper elaborates on the research questions addressing "What effects does the integration of ALEKS, an artificial intelligence, web-based software program, have on the achievement, self-efficacy, engagement and attitudes towards mathematics of 11th grade geometry students?" Baseline data was collected on the students and a theoretical framework justified the need for the study. A research plan was developed that would collect and analyze data over a period of six weeks that would best answer the research questions. Results showed that ALEKS had a positive impact on student achievement, although the results were not statistically significant. Results also showed that ALEKS positively impacted the self-efficacy and attitudes of students by aiding in their understanding and enjoyment of mathematics. Lastly, an action plan was developed that delineates the next steps in the study. The teacher researcher will share and communicate results of this study and implement action steps that involve further exploration of the impact of ALEKS when used in a high school setting.

keywords: intelligent tutoring software, ALEKS, mathematics, achievement, Geometry, engagement, attitudes, self-efficacy

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CHAPTER 1

INTRODUCTION

Algebraic reasoning furnishes the foundations for the development of abstract mathematical understanding. It is alarming however, to know that “three fourths of U.S. eighth graders enter high school not proficient and therefore not prepared to move to a higher level of mathematics” (Schmidt, 2012, p. 134). Much of this weakened mathematics performance can be attributed to the passive learning experiences students receive in the mathematics classroom (Wess & Pasley, 2004). Our current methods of instruction are far from following Dewy’s beliefs that genuine education is derived through experience (Dewy, 1938). Similar weaknesses can be shown in the mathematics achievement of Geometry students at Achieve High School. Teachers convey information and demonstrate mathematical reasoning where students are attentively listening and taking notes, and sometimes solving mathematical problems themselves. Endless hours and immeasurable efforts, both independent and collaborative, are poured daily into planning and executing lessons. Yet the comment “I know I taught this, but they just forgot!” represents simply the tip of the mountain of the frustration that overwhelms teachers when their students perform poorly on an assessment due to not being able to retain information or understand mathematical processes or both. The proposed action research is based on the research questions that ask whether or not the implementation of Intelligent Tutoring Software (ITS) systems impacts the achievement, self-efficacy, engagement, and attitude towards mathematics of 11th grade geometry students.

Problem of Practice Statement

A prevalent problem of practice at Achieve High school is that the majority of students struggle in retaining the mathematics we teach them. While the End-of-Course (EOC) Algebra 1 examination scores showed that only 43% of students passed the Algebra 1 EOC, the Measures of Academic Progress (MAP) assessment at the beginning of the year showed that 60% of students scored below the 9th grade level mean score. Students who have weak Algebra 1 foundations have a detrimental effect on the strength of the overall mathematics program, as lack of strong mathematical foundations, motivation, or both have led to the majority of students opting out of even attempting the pre-calculus course as their capstone math course.

Low academic achievement is a common thread weaved throughout grade levels, mathematics subjects and students of different racial backgrounds. While there were 228 students attempting an Algebra 1 unit in the ninth grade, there were only 62 students attempting a pre-calculus credit as seniors. The disparity of achievement is even bigger when comparing students of different racial background. Although 52% of students in Algebra 1 as freshmen are African American, only 30% of students in pre-calculus are African American as seniors. In geometry alone, while Caucasian students had an average of 81% in Algebra 2 (the prerequisite course), their African American counterparts had an average of 70% in Algebra 2. Forty-five percent of all students have either a D or an F as a final grade in geometry. In addition, thirty percent of those low-performing students were African American. Embedded within that huge problem of failure to retain information lies the specific problem of practice for Achieve High school of low achievement rate for geometry classes, which further points out the intersection of low mathematical ability with the lack of motivation or engagement to reach mathematical solutions.

Evolution of the problem of practice. A problem of practice is collectively owned by members of an organization and revolve around focal practices that need improvement within an organization (Mintrop, 2016). The effects of this problem of practice were pervasive enough so that the teacher-researcher was offered a new position of mathematics coach simply to focus on the mathematics instruction occurring within the classrooms. Upon informal observations of the Algebra 1, Algebra 2 and geometry classes during a four week instructional cycle, the teacher-researcher noted that students had a passive stance towards their learning, and, that although they were not visibly disruptive, the majority of the students were not engaging in the lessons by asking/answering questions or actually using mathematical procedures to solve problems.

The initial impression of the teacher-researcher was that educated and capable teachers stand before young people that appear to be ready to learn, at least on the surface, yet mathematics standardized test results indeed show that little learning has taken place. While there are currently 228 students enrolled in Algebra 1 classes, there are only 62 students enrolled in the senior pre-calculus course. Due to a lack of achievement or motivation or both, it is disheartening that only 20% of current seniors are enrolled in the capstone mathematics course of pre-calculus that is offered at Achieve High School when 100% of freshmen are involved in Algebra 1 or Algebra 2 honors.

National context. There is a tremendous pressure on teachers and administrators to raise student achievement and increase standardized test scores. Signed into a law by President Bush in 2002, the No Child Left Behind Act of 2001 (2002) significantly increased the federal law in holding schools accountable for the academic progress of the students. It continues to hold schools accountable for academic growth of all subgroups, highlighting a specific intent to close the achievement gap. Despite this overarching mandate to raise mathematics achievement and close the achievement gap, only 34% of eighth-grade students in the United States scored at or above the proficiency level on the 2009 National Assessment of Educational Progress in mathematics (National Center of Educational Statistics, 2009).

The pattern of low mathematics achievement has continued to persist in the United States. Although thirteen-year olds scored higher in mathematics in 2012 than the previous assessment years, the average scores for seventeen-year olds in 2012 was not measurably different than in 2008 (National Center of Educational Statistics, 2014). "Mathematics achievement is an important predictor of success" (Huang, Craig, Xie, Graesser, & Hu, 2016, p. 258). In fact, Ritchie and Bates (2013) found that performance on mathematics tests at age seven significantly predicts the socioeconomic status of a person at age forty-two.

Purpose of the Research

The purpose of this proposed research study was to measure the effects of mathematical Intelligent Tutoring Software (ITS) systems on the achievement, self-efficacy, engagement and attitudes towards mathematics of 11th grade geometry students. The term achievement has many dimensions, but for the purposes of this research it is bounded by the academic performance of students on two cumulative assessments that measure their ability to apply geometry theorems in mathematical contexts. Similarly, this paper frames the complex term motivation within the boundaries of self-efficacy towards mathematics. Self-efficacy refers to an individual's belief in his/her capacity to execute behaviors necessary to produce specific performance attainment (Bandura, 1997). Student engagement is also a multidimensional concept referring to a student's psychological investment in the learning, understanding or mastering content knowledge (Newmann, Wehlage & Lamborn, 1992). For purposes of this study student engagement is measured more along the continuum of behavioral engagement, measuring student behaviors regarding concentration, attention, persistence, effort, asking questions and contributing to class discussions (Fredericks, Blumenfeld & Paris, 2004). Lastly, student attitude is confined in this study to measuring the positive or negative feelings that students possess towards learning, mathematics, and generally towards learning using technology.

The field of ITS systems consists of computer-based learning systems developed with artificial intelligence techniques (VanLehn, 2006). This artificial intelligence is what enables the ITS software to function in the role of a human tutor, guiding and correcting the student through the learning process. At the pulse of ITS lies instructional feedback which has demonstrated significant learning benefits (Hattie & Gan, 2011). Utilizing adaptive learning technology, ITS systems adapt to the unique academic needs of each learner (Taylor, 2008). So ITS systems differentiate instruction to guide the student through learning new content while utilizing corrective feedback throughout the process.

The overarching goal is to increase mathematics achievement and help students develop a positive attitude towards mathematics. The long term school-wide goal is to strengthen the mathematical foundations of Achieve High School's geometry students while increasing the number of seniors enrolled in the pre-calculus course which directly follows geometry in the teaching sequence. Through increasing mathematics achievement and improving the disposition of students towards mathematics, Achieve High School is committed to increasing student achievement in mathematics classes.

The literature suggests that using different technologies in the mathematics classroom show improvement in student attitudes toward learning, higher achievement, and improved engagement with mathematics (Avci, Keene, McClaren, & Vasu, 2015). Adaptive learning technology systems attempt to address issues with motivation that face schools today through adapting instruction to learners' prior knowledge, personal preferences, and need for timely assistance (Walkington, 2013). This proposed research study will investigate the impact that ITS have on achievement, self-efficacy, engagement, and attitude towards learning of 11^{th} grade geometry students.

Research Questions

1. What are the effects of ALEKS on 11^{th} grade geometry students' skills of applying Geometry theorems in mathematical contexts?
2. What are the effects of ALEKS on self-efficacy of 11^{th} grade geometry students?
3. What are the effects of ALEKS on student attitudes of 11^{th} grade geometry students?
4. What are the effects of ALEKS on student engagement of 11^{th} grade geometry students?

The Significance of the Study

This study has a potential to impact the classroom instruction across secondary levels in many areas of interest. If indeed students show high levels of engagement and motivation when using intelligent tutoring software, then teachers need to increase use of such software/programs during the academic day. This study has a further potential in working towards closing the achievement gap if minority students show measurable growth in academic achievement. If technology indeed acts as an equalizer across gender, race, and socioeconomic status, then it is possible that more females, minority students, and students of impoverished backgrounds can develop a bigger affinity and a stronger foundational skill set for the subject of mathematics. We live in an era when technology is permeating our daily lives faster than we ever fathomed. Educationally, however, we need to be certain that our time investment in online learning systems is indeed significant in changing the lives and the academic foundations of the students.

Lastly, if this study yields high achievement in geometry, then it can be expanded vertically downwards to the Algebra1 and Algebra 2 populations and upwards to the pre-calculus population at the current research site of AHS. This could also potentially increase enrollment in more rigorous higher level senior mathematics courses (i.e. pre-calculus or calculus). Furthermore, the possibility of a larger number of students entering mathematics related fields in their college studies remains a true aspiration. Lastly, the results of this study could further point to ways to narrow the achievement gap among low socio-economic subgroups.

Scholarly Literature

The focus of this literature review is to discuss the effects of incorporating web-based ITS systems on mathematics achievement and motivation of students. In incorporating action research procedures, one of the early steps of the process is to review the literature with the purpose of helping the practitioner-researcher make informed decisions about the research focus and plan (Mertler, 2017). This literature review section of Chapter One is aimed at discussing the foundational concepts along with the theoretical framework of ITS systems such as ALEKS, and the impact in areas of classroom environment, student motivation, and mathematics achievement. The theoretical framework of this study is comprised of concepts grounded in constructivist theory, cognitivism, mastery learning theory, self-efficacy theory, and behaviorist theories of reinforcement. The purposeful selection of different aspects of these theories is interwoven through this discussion of the literature.

Learning and Intelligent Tutoring Software systems. One of the ways to meet the various mathematical ability levels found in the high school setting is through the use of computer based interventions such as ITS systems. An example of a particular ITS system is the Assessment and Learning in Knowledge Spaces (ALEKS) web-based software system (ALEKS Corporation, 2017). ALEKS software uses adaptive questioning to determine a student's background knowledge and then chooses an instructional learning path on what the student is ready to learn. ALEKS is built upon Knowledge Space Theory (KST), which provides the founding principles for adaptive tutoring and problem-solving systems (Falmagne, Albert, Doble, Eppstein & Hu, 2013). According to KST, a subject such as geometry can be divided into groups of problem types covering specific concepts as demonstrated in Figure 1.1 below. A student's collective knowledge is described by a set of problem types that he is capable of solving, called a knowledge state (Falmagne et al., 2013). A knowledge space is the collection of all of the knowledge states in a population, and Knowledge Space Theory allows an academic subject to be represented by the computer's memory as an enormously large number of possible knowledge states (Falmagne et al., 2013). The following figure illustrates the collection of some of the knowledge states that formulate the study of high school Geometry (ALEKS Corporation, 2017).

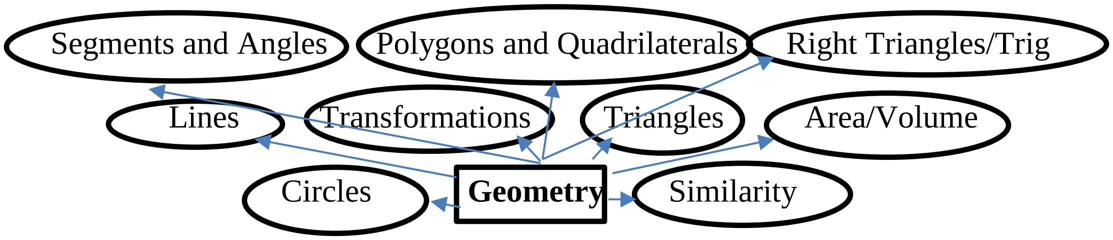


Figure 1.1. Sample knowledge space for geometry.

Learning new content thus occurs through the interaction between students and the software. Constructivist theory advocates that students construct knowledge and meaning based on their experiences (Kant, 1959). As students are experiencing learning, they experience questions, challenges, and setbacks. Through the utilization of an ITS system to maneuver through those obstacles, the student is thus reflecting on his/her own learning as he/she is experiencing academic growth. According to constructivist theory, the teacher encourages discovery of concepts through assignments/experiences that endorse active involvement of students (Anderson, 1982).

Employing ITS systems while learning new content also has roots in mastery learning theory, which highlights the importance of the role of feedback during the learning process. Bloom (1968) organizes learning that establishes a level of performance that all students must master before moving on to the subsequent units. Learning looks different for everyone when taking into consideration the variant background knowledge and skill levels of the students (Bloom, 1968). In solving a mathematical problem, a student may engage in interpreting, recalling, organizing, planning, and producing in order to arrive at a solution (Anderson et al., 2001). An effective technology system may enable the intersection of these higher order thinking skills with the individualized mathematical needs of students in order to begin filling gaps in content that prevent high mathematical achievement. In reviewing over 700 empirical studies where students incorporated computer-based instruction as part of their instruction, Schacter (1999) concluded that the students showed overall positive gains in achievement across standardized and national tests.

One of the most challenging tasks for educators is to give constructive feedback to students that in turn guides them in their goal to learn or master new content. Knowledge Space Theory is anchored on giving specific feedback on what a student knows, does not know, and is ready to learn next (Falmagne et al., 2013). The student then employs a choice as to which topic they wish to study and master, given only the choices of the topics that they are ready to learn. “ALEKS provides the mechanisms for the development, monitoring and adjustment of individualized programs required for implementation of a successful mastery learning program” (Hagerty & Smith, 2005, p. 185). Using an online ITS system such as ALEKS will help develop and monitor an individualized learning plan for each student.

Behaviorism and cognitivism. A relationship exists between the mathematics classroom environment and the academic achievement of students. Behaviorist theory of reinforcement holds that learning is based on the idea that all behaviors are acquired through conditioning that occurs through the interaction with the environment (Skinner, 1968). Psychological, social and cultural influences affect students’ expectancies for success (Gilbert et al., 2014). The teacher sets the tone for the overall classroom environment. Teacher support, however, often defined as student perceptions of the teacher's caring for students and willingness to help them is one of the important aspects of the mathematics classroom environment that is often missing (Trickett & Moos, 1973). "Students' perceptions that their teachers believe that they are capable of learning and understanding mathematics positively relate to their mastery and performance goal orientations" (Gilbert et al., 2014, p. 300). All educators, however, have witnessed the self-defeated looks of students receiving back on a graded assignment in which they performed poorly. Students look for their behaviors to be reinforced, and poor grades serve as a negative reinforcement, thus decreasing their drive to learn. It is almost as though teachers witness the moment that students lose belief in themselves, their mathematical ability, and their teacher.

Educators strive for students to remember and apply what they have learned while building connections between the new knowledge to be gained and prior knowledge. Anchored in cognitivism, learning is viewed as an active process that places emphasis on how knowledge is acquired, processed, stored, retrieved, and activated (Anderson, Reder & Simon, 1997). "Two of the most important educational goals are to promote retention and to promote transfer" (Anderson et al., 2001, p. 63). In an effective mathematics classroom one should see "implementation of a district and state curriculum that includes essential skills and understandings for a world of calculators and computers" (Leinwand, 2009, p. 59). Technology is essential in teaching and learning mathematics, and it should be used to influence the mathematics that is taught and to enhance student learning (NCTM, 2000). So, technology can be seen as a learning aid that facilitates a better processing, storage, and retrieval system for new knowledge. An ITS system such as

ALEKS enables the content to be strategically chunked and reinforced through targeted instruction and assessment strategies (Falmagne et al., 2013).

Motivation and self-efficacy. One of the most difficult tasks for a teacher is to motivate the student at that moment when he/she is experiencing failure. “Motivation enables goal-directed behavior and is evident through action” (Toure-Tillery & Fishback, 2014, p. 331). In discussing different dimensions of motivation, one must consider the disparities between outcome-focused (extrinsic) motivation and process-focused (intrinsic) motivations (Toure-Tillery & Fishback, 2014). Although we ultimately want our students to study because they want to understand the mathematical theory and processes, it is more often that they study because they want that extrinsic reassurance of a good grade. An ITS system incorporates both types of feedback, since with every new topic learned they increase the percentage of mathematical knowledge and receive motivation and tailored guidance from the software along the way.

At the heart of motivation lies a student’s self-efficacy, which influences the rest of his/her academic pursuits. “Mathematics self-efficacy is a student’s confidence to learn and succeed in mathematics” (Naz, Shah & Rehman, 2016, p.2). Self-efficacy influences the choices a student makes, the effort that he/she puts forth, and how long he/she persists when confronted with obstacles. According to Bandura’s social cognition model, a student’s level of motivation, affective state and actions are based more on what they believe than what is intended by academic instruction (Bandura, 1997).

Impact of ALEKS on academic achievement. Although research exists about the impact of ALEKS on academic achievement in an after school setting (Craig et al., 2013) and at the college remedial/entry level mathematics setting (Hagerty & Smith, 2005), there exist no findings at the time of writing this research about the effect of using ALEKS during the instructional day in a high school setting. “Technology has been shown to have a positive impact on student learning in mathematics” (Craig et al, 2013, p. 496). The decreased amount of assistance needed by students while on ALEKS points to an added value for using the technology enhanced program. “The blending of assistance from the teacher and ALEKS could improve the students overall improvement in the after-school program” (Craig et al., 2013, p. 501). When used at the college level in remedial/entry level mathematics courses, ALEKS software system has also positively affected student achievement (Hagerty & Smith, 2005). Students who used the web-based software showed significant improvement in mathematical gains when compared to students who were taught college algebra with the traditional approach (Hagerty & Smith, 2005).

Common mathematics achievement gaps. One of the most prominent problems in education is the achievement gap, which is often related to social justice issues. In terms of mathematics achievement, trends show that the gap between minority and white students persists and may even be widening (Johnson & Kritsonis, 2010). Furthermore, achievement differences only get larger as the topics increase in complexity and can be attributed to teacher quality and expectations (Johnson & Kritsonis, 2010). “Teachers form different expectations of students as a function of race, gender, and social class” (Johnson & Kritsonis, 2010, p. 5). Additionally, minority students are more likely to be taught by less experienced teachers with weaker pedagogical knowledge.

Achievement in mathematics has also historically varied greatly by gender, and a portion of that variance can be attributed to self-efficacy. Educators are audience to the self-declarations of students prophesizing their failure in a class simply because they have never been good in a particular subject. Generally, boys tend to show a greater self-efficacy in science and math whereas girls, when challenged in mathematics tend to see this as a fixed or innate problem thus taking fewer risks with learning something new (Naz et al., 2016). In the high school classroom, girls are sometimes perceived as shy and quiet, and many times they are not as quick to answer questions as their male classmates.

A possible equalizer for racial/ethnic and gender differences could be the use of an ITS such as ALEKS. In a study conducted with sixth grade students in an after-school setting, it was found that ITS benefitted especially disadvantaged individuals and groups thus reducing the achievement gap (Huang et al., 2016). The artificial intelligence software tailors the instruction based on the need of each different student in a manner that's very difficult if not impossible for the teacher to do (Huang et al., 2016). "Thus ITS can benefit especially disadvantaged populations such as African-Americans, girls, and students from low-SES schools, since they are likely to be ignored by human teachers" (Huang et al., 2016, p.262).

Positionality

Reflecting on the positionality of the teacher-researcher is paramount to ensuring the validity of action research. The researcher's beliefs and value systems were inseparable from the research process. The personal experiences of the teacher-researcher converged with the research as she already uses technology as part of the instructional process. The teacher-researcher was continuously seeking new ways to engage and motivate students and believes that intelligent software technology gives students an advantage in mathematics education that stems from the plethora of targeted, individualized practice. The teacher-researcher did remain objective, however, as she needed to interpret the data collected in a holistic and candid fashion, not allowing her personal beliefs to influence any of the conclusions that are made. The positionality of the teacher-researcher has evolved over time as technology was not originally a part of her educational journey, and she did not initially view technology an essential tool to effective teaching. Lastly, the teacher-researcher originally initiated the use of technology as she felt it could help narrow the achievement gap through benefiting all student populations, especially the disadvantaged individuals or groups.

Role of teacher-researcher. The teacher-researcher is a National Board Certified Teacher and has taught at AHS for the past eighteen years and has a Master's in Secondary Mathematics Education and a Master's degree in School Administration. She currently serves as the mathematics coach for AHS. She has served as an assistant principal for two years and as the department chair for the past thirteen years. The teacher-researcher has taught all levels of college-preparatory courses including Algebra 1, Algebra 2, Geometry and Pre-Calculus along with Intermediate Algebra which enrolled only students who were weak in mathematics and struggled with Algebra 1 as ninth grade students. Additionally, the teacher-researcher continues to teach both honors and non-honors levels of geometry, which including the above courses has allowed her to be exposed to the diverse ability levels of the students of AHS. By being offered the position of mathematics coach in the fall semester of 2016, the teacher-researcher was given the broad goal of improving mathematics instruction.

With vested interest in strengthening the mathematics program at AHS, this teacher-researcher teaches two blocks of geometry classes and works with other mathematics teachers the remainder of the day. Provided with no precedence for this position at Achieve County School District and with the long-term goal of lowering the failure rate in mathematics curriculum, the teacher-researcher is planning to investigate the impact of ALEKS with her own two sections of geometry students first.

The teacher-researcher holds the role of an insider for purposes of this study, as the scope of this research is within the researcher's own work practice. She is in a unique position to investigate and make changes to a practice situation that is pertinent to her community of learning. Considering her long tenure at AHS, she understands the internal challenges of the organization as a whole and the cultural challenges of the student population.

Ethical implications of teacher-researcher. The teaching profession, just like many other professions, adheres to a code of ethics as teachers, students, and all school personnel work towards helping students achieve personal and academic excellence. "The educator therefore works to stimulate the spirit of inquiry, the acquisition of knowledge and understanding, and the thoughtful formulation of worthy goals" (NEA, 2013, as cited in Dana & Yendol-Hoppey, 2014, p. 148). It is imperative that the direction of the action research study should always have the best interest of the student as the ultimate guiding principle. Additionally, as the teacher-researcher and as the mathematics coach, it is imperative to communicate openly with all the stakeholders about the intent of the study.

Since all geometry students of a particular section of the teacher-researcher were utilizing ITS systems during their respective mathematics class time, the teacher-researcher does not feel that she is embarrassing, angering, or simply isolating any one particular student. In order to protect the anonymity of the subjects, all students were assigned a pseudonym. The only students who were allowed to participate were the ones with signed permission from their parent. No fear existed of singling any student out since all students that belong to the teacher researcher were offered the opportunity to participate. The focus interview was done in a small private group in efforts to protect students' privacy and to enable them to speak freely. Lastly, this research was conducted through adherence to district guidelines for research.

Research Design Methodology Summary

This action research study utilized a quasi-experimental, convergent mixed-methods design with the goal of measuring the effects of ITS systems such as ALEKS on mathematical achievement, self-efficacy, engagement, and attitudes of geometry students. Action research is conducted by teachers within their own classrooms in order to better understand and improve the quality of their instruction (Mertler, 2017). The teacher-researcher conducted this research in her own school while focusing on the unique characteristics of her own students. A convergent mixed method research design employs both a quantitative and qualitative approach to conducting research (Mertler, 2017). In order to address the research questions of this study, the teacher-researcher triangulated the data. Triangulation of data, or the use of multiple data collection methods and sources will ensure the validity, credibility, and dependability of the data (Mertler, 2017). A quasi-experimental design comes closest to a true experiment but there is still no random assignment of group members to the different groups (Mertler, 2017). This study implemented a pretest-posttest control group design, where one of the geometry classes was assigned the treatment (ALEKS software usage) and the other one served as a control group.

The research site. Achieve High School is a rural high school of 1,374 students in the small rural town of Dreamtown, South Carolina. The school has a demographically diverse population with 1% Asian, 2% two or more races, 39% Caucasian, 8% Hispanic, and 49% African American (S.C. Department of Education, 2016). The poverty index of AHS is high with 70% of the students receiving free/reduced lunch. The school has a student to teacher ratio 26:1 in core subject classes and 53% of its faculty members hold advance degrees (S.C. Department of Education, 2016). The school follows a 4 x 4 block schedule while the ninth-grade students belong in the ninth-grade academy and have yearlong English, mathematics, and social studies classes that are 55 minutes in length. All of the remainder of the classes are 90 minutes long and they meet 5 days a week for 90 days.

According the most recent data available from the census Bureau (2015), the town of Dreamtown, South Carolina, has 8,801 residents with a median age of 40.6 years old. The town has an unemployment rate of 8.7%, which is considerably higher than the 6% unemployment rate of the state of South Carolina. Perhaps the biggest influencing factor in the economy of the town of Dreamtown and the unemployment rate is the closing down of the Springs factory in 2007. Employing near 1000 workers for nearly 120 years, this textile plant specialized in bedding and home fashions and it closed its doors to move operations off shore. The textile plant offered an easy alternative to students who did not wish to entertain the thought of higher education by offering them a decent paying job close to home. Consequently, these students did not traditionally choose to take challenging academic courses since college was not usually part of their future. The most recent statistic is that 73% of the graduating seniors in 2016 and 72% of the graduating seniors in 2015 are attending college. The more alarming statistic, however, remains that 32% of last year's graduating class was enrolled in a remedial math course in college (guidance report, n.d.).

Participants of action research study. The participants of this study were 45 11th grade students enrolled in college-preparatory geometry led by the teacher-researcher. This group of participants represented a convenience sample of 45 students taught by the teacher-researcher, and they are divided in two separate classes. This was an ethnically diverse group, where 23 students were African American, 12 were Caucasian, nine were Hispanic, and one was multi-racial. There were 19 males and 24 females. Seventy-one percent of students (N=32) were receiving free or reduced lunch at school (data retrieved from PowerSchool, 2018). There were two students that understand minimal English (level 1 proficiency) and chose to work the ALEKS software in the Spanish language. Eight students had an Individualized Education Plan that addresses accommodations due to various learning disabilities.

The students came from various academic and social backgrounds. Over half (N=29) of the students made a D or a C in Algebra 1 and only 15 made a B or better (data retrieved from PowerSchool, 2018). Nearly a third of students (N=14) had a D or a C in Algebra 2. Nine students were repeating the course due to prior failure of low grades or due to attendance issues. Thirty-eight percent of the students (N=17) indicated they held a part-time job after school at various food service and retail establishments within 20 miles of the school. Fifty-eight percent of the students came from single parent homes or blended family environments, and 100% of the students indicated a desire to extend their education past high school into a four-year institution.

The achievement gap is clearly visible within the context of this research study and among the research participants, as the mathematical performance of African American students is lacking when they are compared to their white peers. The majority of the low-achieving students in geometry are African American (67%), and only 30% are opting to challenge themselves with pre-calculus or calculus as seniors. The poverty index is also high for Achieve High School, with 75.6% of families receive financial assistance from the federal government through programs such as Medicaid, Supplemental Nutrition Assistance Program (SNAP) or Temporary Assistance for Needy Families (TANF) (South Carolina Department of Education, 2016). Students at AHS clearly need and utilize the support systems to progress economically and this need is also present in order for them to progress academically. Therefore, students of low socioeconomic background and racial minorities need extra resources such as ALEKS to enhance their learning experiences and be successful in the academic setting.

Intervention. The intervention in this study is ALEKS, an ITS system that is web-based and utilizes artificial intelligence in order to teach and assess pedagogical content. For the duration of the six weeks of data collection, one of the two geometry classes was assigned to the ALEKS intervention and used the software for two hours per week while the other geometry class was taught using traditional, standards-driven instruction. Several data collection methods were devised in order to address the four research questions of this study.

Data collection methods and instruments. This research study included both quantitative and qualitative data collection methods. For purposes of this study, achievement was bounded by the performance of students on two cumulative geometry assessments. The data collection method to address the first research question of examining the effects of ALEKS on 11^{th} grade geometry students' skills of applying geometry theorems in mathematical contexts was the administration of a pre-test and a post-test to both the experimental and the control groups. The instruments to measure student performance consisted of two cumulative concept-based geometry assessment comprised of 32 open-ended questions each, organized in two units for the purpose of this study. The assessments used to measure how well students are applying geometry theorems in mathematical contexts were created by the teacher-researcher and aligned with South Carolina course standards for geometry. Students in both groups completed the same pretest at the onset of the study, prior to the instruction of the first unit, and the same posttest at the conclusion of the first unit in three weeks. Similarly, all participants completed a second pretest at the onset of the second unit and posttest three weeks later. End of course examination scores from the previous year were available to the teacher-researcher along with current Measures of Academic Progress (MAP) scores administered to all geometry students at the onset of the action research. Both of these data points were used as baseline data with the purpose of describing the student population and possible expansion of the research for further studies.

In order to investigate the effects of ALEKS on student motivation, this research defines motivation within the boundaries of mathematics self-efficacy of student participants. In order to address the second question, what are the effects of ALEKS on student motivation, the teacher-researcher administered the student survey at the onset of the study, as well as at the conclusion of the study at the end of the six-week data collection period. The instrument for data collection is "Mathematics Self-Efficacy Questionnaire" (MSEQ), that was modified by the teacher-researcher from an original MSEQ used to measure self-efficacy and anxiety towards mathematics (May, 2009). Only the items pertinent to self-efficacy are being used in this study. It included 18 Likert-type questions that are created to measure self-efficacy belief of students (see Appendix A). "Rating scales can be used very effectively to measure students' attitudes, perceptions, or behaviors" (Mertler, 2017, p. 140). The mathematics self-efficacy questionnaire utilized a five-point scale in order to allow for valid differentiation between responses.

In measuring student changes in attitudes towards mathematics, the teacher-researcher administered a Student Attitude Survey (SAS) using a five-point Likert scale instrument (Appendix B). This survey was developed by Brookstein, Hegedus, Dalton, Moniz & Tapper (2011) in order to measure student attitudes and beliefs towards mathematics. The SAS survey was developed as part of a quasi-experimental intervention study involving the use of software technologies in a mathematics classroom, and the validity of the instrument was verified prior to collecting the data in the study (Brookstein et al., 2011). This survey was comprised of 27 items designed to measure attitudes about mathematics, school, and technology (Brookstein et al., 2011). This survey aimed at addressing the third research question, investigating the effects of ALEKS on the student attitudes of 11th grade Geometry students. The responses to the questions on the survey ranged from "0-strongly disagree" to "4-strongly agree". A sample question was "I enjoy using a computer when learning mathematics" (Brookstein et al., 2011, p. 13). Students in both the experimental and the control group completed this survey at the onset of the study and at the conclusion of the six-week data collection period.

Data collection on the effects of ALEKS on student engagement materialized through the student engagement daily questionnaire (Appendix C). This instrument was created by the teacher-researcher and pilot tested with a group of geometry students in the spring of 2018. The answers provided by the students were aligned with the teacher researcher's observations of the level of engagement. This instrument was created with the intention to provide both quantitative and qualitative data. First, students rated how they place their level of engagement and how they felt about practicing the intended objectives on a five-point Likert-scale. But in addition, they also justified their answers on two free-response questions that followed, stating why they rated themselves in the way that they did.

Data collection can be used to shift gears midway through inquiry and adjust the original plan as necessary (Dana & Yendol-Hoppey, 2014). Field notes documenting student engagement (Appendix D) and small-group focus interviews exploring student motivation and classroom engagement (Appendix E) were utilized to reflect on results of the study and determine the next steps. Since this research intended to measure achievement along with students' self-efficacy, attitudes, and engagement, multiple methods of data collection were necessary in order to appropriately answer the research questions. Action research is cyclical, aimed at improving education by teachers collectively leading and incorporating instructional changes (Mertler, 2017). The qualitative data derived from the field notes and the interviews helped contribute to the triangulation of the data collected from cumulative concept assessments and student surveys/questionnaires.

Data analysis. All quantitative data was analyzed using descriptive statistics, including both measures of central tendency and variability. Descriptive statistics are commonly used when trying to describe a collective level of performance or attitude of a group of participants (Mertler, 2017). In order to analyze student achievement, the teacher-researcher statistically analyzed and interpreted both the participants' final posttest scores and their gain scores using descriptive statistics. In addition, the teacher-researcher also utilized descriptive statistics in order to analyze responses on the SAS survey and the mathematics self-efficacy survey. Through this analysis of the quantitative data, the teacher-researcher highlighted measures of central tendency and variation among the responses.

The field notes and the focus group interviews provided qualitative data that was processed for themes or patterns. Since qualitative data are narrative, the data themselves are words (Mertler, 2017). The field notes and the semi-structured focus group interviews allowed the teacher-researcher to look for patterns that may have not otherwise presented themselves in the quantitative responses. These two instruments helped with triangulation of the data in addition to providing insight that the quantitative data is not capable of doing.

Limitations

This study was limited to 11^{th} grade geometry students at a rural high school in South Carolina. Since this study was conducted in a single geographical area, results may differ when applied to a high school in a different sociocultural setting. The sample size was small (N=45) and the teacher-researcher has no control over students transferring/dropping out of school and thus this study. A limitation regarding this particular intervention is that the ALEKS software does not allow the student to move forward unless they have mastered a certain group of objectives. This resulted on some students spending too much time on a certain group of problems, thus presenting a challenge for students to be fully prepared for the cumulative assessments as delineated in timeline on this study. The teacher-researcher was keenly aware of the pace and progress of each individual student. Lastly, the teacher-researcher examined and confirmed similarity between the participants in the two groups prior to data collection since the groups were not randomly assigned.

Ethical Implications of Conducting Action Research

Data collection in action research is the primary responsibility of the teacher-researcher, who in turn has to ensure that it occurs in an ethical manner in order to protect the privacy of each individual student. Since the participants of this research study were minors, they were not of legal age to give their consent to participate in a research study (Mertler, 2017). Therefore, a parental consent form was signed by their parents, giving their child permission to participate in the study. In addition, all students completed an assent form which gave the teacher-researcher the child's permission to participate in the research. An assent form is a form completed by an individual who does not have the authority to consent to participate in a research study (Mertler, 2017). Permission from parents of minors and the students themselves need to be attained if the data that's collected is intended to be shared with a broader audience bigger than the school faculty (Mertler, 2017). Since the teacher-researcher may wish to share findings at the district level or perhaps even a conference, parent consent forms and student assent forms were obtained. Once the data was collected, the teacher-researcher ensured that it was secure and confidential, thus protecting the identity of the students and the teachers alike (Mertler, 2017). Pseudonyms were assigned and used for students and teachers in order to respect the anonymity of the participants. All students who did not voluntarily turn in a consent form signed by their parents and/or an assent form consenting to the study were omitted from this study without penalty.

It is not crystal clear at what point teaching becomes research because of the duality in the purposes of generating knowledge and achieving a practical end (Dana & Yendol-Hoppey, 2014). Conducting research involves orchestrating many actions of teachers and students alike both of which are founded on building strong relationships with both entities. The overarching role of ethics in teaching and/or researching highlights having fair, open, and caring relationships with students, teachers, administrators and other staff (Dana & Yendol-Hoppey, 2014). Since teaching affects research and research affects teaching, the two concepts are so intensely intertwined that it is difficult to state a specific point of separation of those two in the continuous cycle of learning.

Summary and Organization of the Dissertation

Action research inspires methodical reflection of our practice and paves the road to a systemic improvement of instruction. Although the research questions may be refined and/or changed throughout the process, the overarching goal remains to analyze the data collected in order to make future informed decisions. The teacher-researcher is concerned with the impact of ITS systems as it relates to student motivation, achievement, engagement and attitude towards mathematics. “Instructional technology is becoming more and more prominent in educational settings, expanding beyond industry and higher education into K-12 environments” (Chappell, Arnold, Nunnery & Grant, 2015). The analysis of the effectiveness of ITS systems can impact when and how to implement similar technologies in order to maximize student achievement, engagement, and across all mathematics classes.

The remaining chapters are organized in order to present the different phases of this action research study. Chapter 2 presents a review of the literature in order to connect the current action research to previously conducted studies and to the theoretical framework that supports this study. Chapter 3 outlines the methodology that is being implemented, the participants in the study, and the data collection instruments that are used in order to address the research questions presented in this study. Chapter 4 presents a statistical analysis of the data and an interpretation of the findings. Chapter 5 presents a summary and discussion of the findings, implications for educational practice and recommendations for action and for future studies.

Glossary of Key Terms

The following terms are pertinent to this Action Research study and will be used throughout this research process.

Adaptive Learning Technology – an interactive teaching device that adapts to the unique academic needs of each learner (Taylor, 2008)

Achievement gap – a significant and persistent disparity in academic performance between different groups of children (U.S. Department of Education, 2012)

ALEKS – Assessment and Learning in Knowledge Spaces – a web based artificially assessment and learning system (www.aleks.com, 2018)

End-of-Course (EOC) examination – comprehensive assessment administered statewide that assesses overall content area knowledge (Spring, 2005)

Individualized Education Plan (IEP) – a plan developed to ensure that a child who has a disability receives specialized instruction and related services (Spring, 2005)

Intelligent Tutoring Software (ITS) - computer software system with problem solving capabilities imitating a human tutor (Anderson, Boyle, & Reiser, 1985)

Knowledge Space Theory (KST) – a structure using mathematical formalisms that describes the possible states of knowledge of a human learner (Falmagne, Albert, Doble, Eppstein & Hu, 2013)

Measures of Academic Progress (MAP) – a computerized adaptive test aimed at making informed decisions in improving a child's academic growth (https://www.nwea.org, 2018)

National Assessment of Educational Progress (NAEP) – the largest nationally representative and continuing assessment that measures what the students know and can do across various subject areas (NAEP, 2015)

No Child Left Behind Act (NCLB) – a federal law mandating standards based educational reform while providing funding provisions for disadvantaged students (NCLB, 2002)

Online Learning System – the facilitation of technology in assigning and delivering online content for courses (Taylor, 2008)

Tennessee Comprehensive Assessment Program (TCAP) – a standardized assessment tool used in public schools in Tennessee intended to reflect yearly learning of content (Huang, Craig, Xie, Graesser, & Hu, 2016)

CHAPTER 2

LITERATURE REVIEW

Mathematics is a tough subject to understand and an even tougher subject to teach. This challenge is derived from the fact that mathematics concepts are highly abstract, hierarchical and interconnected, and the dominant mode of instruction remains teacher-centered (Nandwa, Wasike & Wanjala, 2015). While secondary mathematics teachers have internalized advanced calculation and theoretical concepts, conveying that content to the learner can be a daunting task and the statistics to support lack of mathematics achievement are abysmal. Only 40% of fourth grade students performed at or above *proficient* in the NAEP mathematics assessment in 2015, and a mere 25% of 12th grade students performed at or above *proficient* in mathematics (NCES, 2015). The most alarming statistic, however, is nestled among the powerful words "achievement gap," a term designed to describe the tremendous gap in mathematics achievement between Caucasian and African American students. Whereas 32% of Caucasian students performed at or above *proficient* level in mathematics, only 7% of African American students performed at or above the *proficient* level (NCES, 2015).

The data above serve simply as road signs waving caution on the road paved by the inability of our students to retain the mathematics we teach them. Student achievement is also signaling trouble at a local level as well. At Achieve High School, 60% of students failed the Algebra 1 End-of-Course examination while 45% of our students had a D or an F in Geometry. Therein lies the specific problem of practice for

Achieve High school of low achievement rate for geometry classes; this further points out the intersection of low mathematical ability with the lack of motivation or engagement to reach mathematical solutions.

Student poor performance in mathematics can be linked to several factors that work against the student making proper gains in mathematics. In order to commence improvement in mathematics achievement, we must examine the root causes of the current low mathematics performance of our students. “It could be a result of several factors such as poor teaching, psychological factors, unpreparedness on the part of the students, poor learning environment, location of schools, and the evaluation process” (Alordiah, Akpadaka & Oviogbodu, 2015, p. 130). Several factors were identified across multiple studies as cited in Alordiah et al. (2015) as being influential in influencing students’ achievement: attitude of students and teachers, study habits, teachers’ qualifications, teaching methods, school environment, government policy, school location, and family type. Therefore, in order to increase achievement, we can begin by attempting to address factors within the scope of this research, such as student achievement and motivation.

The purpose of this study is to examine the effects that a particular intelligent tutoring software (ITS), ALEKS, has on student achievement, self-efficacy, engagement and attitudes towards mathematics. Assessment and LEarning in Knowledge Spaces (ALEKS) is an internet-based artificial intelligence program that uses adaptive questioning in order to address a students’ knowledge in particular topic and consequently instructs the student on the topics that they are ready to learn (ALEKS, 2017). In a quasi-experimental, convergent mixed methods study, this study is seeking the answer to the research question investigating the effects of the integration of ALEKS, an artificial intelligence, web-based software program, have on the achievement, self-efficacy, engagement and attitudes of 11th grade geometry students.

Extent and Nature of the Literature Review

The purpose of a literature review is to present the current literature of a research topic as it provides the key ideas, theories, and significant terminology in order to establish a theoretical framework for a research study. "A successful literature review constructively tells the reader about what has been learned" (Webster & Watson, 2002). A literature review synthesizes current knowledge on a topic while defining an issue for further study (Machi & McEvoy, 2016). Reviews of the literature can be simple, where the purpose is to argue a position about the current state of knowledge on a topic, or complex, which aims to review the literature to uncover a research problem for further study (Machi & McEvoy, 2016).

The purpose of this literature review is to establish a theoretical framework for the use of adaptive learning technologies (specifically ALEKS) in the high school mathematics classroom. It is the aim of this chapter to establish the context for the current literature in this field while defining key terms and elaborating on theories framing the existence and importance of intelligent tutoring systems in education today. This chapter starts with deliberating on select topics in the current state of education in the United States followed by a discussion of historical perspectives that form the storyboard of the development of technology in the American education system. Additional discussion follows on the progression of reform efforts in public education as they relate to this topic. The review includes research findings of past studies on ALEKS and its effects on mathematics instruction at different levels within the public education system.

The thematic framework around this study consists of theories that serve as the foundations for the development of ITS systems such as ALEKS. A purposeful selection of theories such as constructivist theory, mastery learning theory, self-efficacy theory, and behaviorist theory of reinforcement will be discussed in the context of serving a theoretical framework for this study. Furthermore, ALEKS was founded upon Knowledge Space Theory, which will also be discussed in this literature review. Lastly, the concept of motivation will be further explored and one specific facet of motivation, self-efficacy, will be further positioned as we examine how it relates to student achievement.

Literature Search Strategies

A search for the literature was conducted using the EBSCO and ProQuest databases. Various forms of the terms intelligent tutoring systems, computer-based instruction, adaptive learning technologies, mathematics achievement, and ALEKS were used in order to form a concept underlay for the literature review. A secondary group of terms emerged after this primary search and terms such as Knowledge Space Theory, achievement gap, motivation, and self-efficacy were used to search for deeper understandings within this study and the Problem of Practice. All sources used were peer-reviewed articles, books, or published dissertations.

Current Portrait of Mathematics Education in the United States

The decline in mathematics performance of United States students has been well documented and a topic of deep concern for educators nationwide. The United States is a member of the Organisation for Economic Co-operation and Development (OECD) group, an organization comprised of 34 democratic countries with market economies who discuss and develop economic and social policy (www.oecd.org, 2018). Every three years since 2000, the OECD performs a Programme for International Student Assessment (PISA) study in order to provide comparable data among countries for purposes of improving educational policies. Among the 34 OECD countries, the United States performed below average in 2012 and ranked 27th (OECD, 2012). In 2015, the US ranked 30th in mathematics and 19th in science among the 35 OECD countries (Desilver, 2017).

But despite continuous efforts to improve our students' mathematics skills, our students continue to perform among the lowest when compared to other countries. One in four US students do not reach the PISA baseline level two of mathematics proficiency and showed particular weaknesses in demands that involve higher cognitive processes and applications of mathematics content to real life situations (OECD, 2012). In a similar cross-national studies, the Trends in International Mathematics and Science Study (TIMSS) administered in 2015, US eighth grade students ranked 8th out of 37 countries in mathematics (Desilver, 2017).

The National Association for Educational Progress (NAEP) is a congressionally-mandated measure of student achievement on a national level. The NAEP was first administered in 1969 and is the largest continuing and nationally representative assessment of what our students know and can do in core subjects (NCES, 2015). An alarming fact is that only 25% of our nation's 12th-grade students performed at proficient level in mathematics (NAEP, 2015). In addition, both fourth and eighth grade students performed lower in mathematics in 2015 when compared to 2013 (NAEP, 2015). Our students are lacking basic mathematics skills and the reasoning abilities that are necessary to be competitive globally in the mathematics arena.

The achievement gap. The current landscape of our education is further defined by the presence of the disparity in performance between the different racial and socio-economic groups. Disadvantaged students show less engagement, drive, motivation, and self-beliefs than advantaged students (OECD, 2012). Reforming public education through valiant efforts of closing the achievement gap has been the goal of education agencies both at the federal and state levels. The U.S. Department of Education defines the term achievement gap as follows:

> Achievement gap: The difference in the performance between each Elementary and Secondary Education Act (ESEA) Subgroup … within a participating Local Education Agency (LEA) or school and the statewide average performance of the LEA's or State's highest achieving subgroups in reading/language arts and mathematics as measured by the assessments required under the ESEA. (U.S. Department of Education, 2012)

President George W. Bush signed the NCLB Act in 2001 aiming to improve education for all students in America by holding schools accountable and leaving no child deprived of a quality education. Through setting high standards for all students and having measurable goals, the NCLB Act of 2001 (2002) sought to advance the American competitiveness while striving to boost the performance of all groups of students, including English-language learners, ethnic minorities, and special education children.

A relationship exists between poverty and low mathematics achievement, and this is further compounded among minority students. Minority children are more likely to attend low-SES schools which often lack quality teachers, possess fewer resources and have more behavioral issues (Kotok, 2017). Thus the academic progression of minority children is much more stymied by these factors. Poverty affects mathematics achievement throughout many channels, and some of them are more complex and not as clearly defined or visible (Friedman-Krauss & Raver, 2015). Children of poverty are more likely to attend lower quality schools, have less qualified teachers, have less exposure to cognitively enriching materials such as books and experience disruptions inside their home environments (Evans, 2004). In addition, children of poverty are more likely to move schools more often which causes disruption in their learning and changes in curricula (Friedman-Krauss & Raver, 2015). Therefore, it becomes increasingly difficult to succeed in sequential academic subjects such as mathematics when the curricula is interrupted and the intellectual development of the children is a bit unstable.

Unfortunately, the achievement gap still exists today and research shows that it widens as a student progresses through the formal education years. NAEP (2015) reports that 32% of white students performed at or above *proficient* in mathematics compared to 7% of black students performed at the *proficient* level or above. In order to narrow this achievement gap, NCLB requires that schools meet requirements of adequate yearly progress (AYP) within all student population subgroups (Farmer, Leung, Banks, Schaefer, Andrews & Murray, 2006). This calls for a keen focus not only on the mathematics content being delivered, but also on the actual delivery methods themselves in order to reach learners of all backgrounds and ethnic groups.

The mathematics teacher today. The need for quality mathematics instruction is higher than ever and there is no consistent of opinion as to what good teaching looks like in the mathematics classroom. This is even more critically present in a classroom led by a novice teacher. Mathematics and policy experts at the National Mathematics Advisory

Panel acknowledge that teacher quality is one issue that needs to be addressed in order to improve the quality of instruction in our classrooms (Hechinger Report, 2010). There is no research supporting the exclusive use of 'student-centered' or 'teacher-directed' lessons; instead, teachers must have a deep knowledge of the math content they are teaching (Hechinger Report, 2010). Teacher preparation programs must incorporate more math content while schools and districts must support less experienced math teachers with professional development supported by strong mentoring relationships (Hechinger Report, 2010). In addition, a novice teacher can also benefit from the further support, guidance and content focus provided by artificial intelligence software such as ALEKS.

Highly qualified teachers have strong pedagogical and mathematical knowledge yet students in schools with high-minority, impoverished populations are more likely to be taught by less qualified teachers, knowledgeable teachers (Johnson & Kritsonis, 2010). Considering about one-third of teachers leave the profession within the first five years yet teacher effectiveness increases sharply after the first few years, the quality and productivity of the education system as a whole is challenged (Darling-Hammond, 2007). Schools are forced to pour more funds to training and supporting new teachers, and schools with low SES indicators are affected the most. Teacher turnover is 50% higher in high poverty schools when compared to low poverty schools (Darling-Hammond, 2007). Thus, the probability of a student having an unseasoned mathematics teacher in high school who is not an expert in his field is considerably high.

Implications for post-secondary studies. The current lack of mathematics achievement impacts education much farther than the high school classroom and the educational and political concerns of standardized test scores. A significant portion of college freshmen are forced to take remedial math courses, despite having passing scores on state standardized tests performing satisfactorily on their high school math coursework (Harper & Reddy, 2013). Colleges and universities are forced to compensate for the lack of mathematical preparation for students by offering tutoring through learning labs and homework centers. Mathematics support through informal mechanisms that run parallel with existing teaching is becoming increasingly available in higher education institutions (Gillard, Robathan & Wilson, 2012).

Yet, in some cases, even the support systems fail to help the struggling student meet the academic demands of even a remedial math class offered at the university setting. Varsavsky (2010) claims that one of the main reasons for students to drop out of college is the lack of mathematics skills. This is particularly concerning as the demand for a college education is higher today than ever. In 1973 only 28% of job requirements demanded education past the high school diploma, whereas in 66% of current jobs require at least an associate degree and 36% require a bachelor's degree in 2016 (Carnevale, Jayasundera & Gulish, 2016).

Educators need to ensure that students arrive at post-secondary studies with strong foundational skills in mathematics in order to be better prepared to meet the current skill demands of our job market. Lack of post-secondary education has a further impact on the economy of our nation. In 2012, the median salary for an individual with a Bachelor's degree was $46, 900 compared to $30,000 of the high school graduate with no college education (NAEP, 2015). This directly affects the unemployment rate and the quality of life within any society. Adult implications of low mathematics achievement include struggles with employment, job performance, budgeting, banking, and problem solving (Vukovic & Siegel, 2010).

Computer-based instruction. Computer-based instruction (CBI) can act as the equalizer that addresses the above factors of weak foundations and low standardized scores, poor teacher quality, and the mathematics achievement gap. According to National Center for Education Statistics (2003), technology aids in the acquisition of higher-order thinking skills, analysis, and problem solving while strengthening teacher-student relationships. Computer-based instruction is a method of learning where a student interacts with the curricula via a computer. Computer-based instruction presents the content in many different forms and aims to tutor and drill students, diagnoses learning difficulties while prescribing remedies for problems, and keep records of student progress (Kulik, 1982). In doing a meta-analysis of 48 comparative studies implementing CBI, Kulik (1982) found that the effect was that CBI raised student test scores from the 50^{th} to the 63^{rd} percentile.

Computer-based instruction is becoming more prevalent in education, particularly in high school. In October 2016, Achieve High School became one-to-one, where every student was provided a Chromebook for the remainder of the school year. An advantage of CBI is that it helps correct inequities in educational opportunities that exist due to race/ethnicity, budget constraints, and substandard teaching (Blaylock & Newman, 2005). Research suggests that CBI could narrow the gap in college readiness among students from diverse demographic backgrounds (Blaylock & Newman, 2005). "Technology can be used to expand, strengthen, and create efficiencies in the delivery of math" (Epper & Baker, 2009, p.4). Through pinpointing strengths and weaknesses, CBI could help high school students obtain significant increases in standardized test scores (Peiro, Merman & Gavilan, 2014).

Theoretical Framework

Computer-based instruction has deep-founded roots in cognitivism. Other theories that shape how learning takes place using computers and specifically intelligent tutoring systems include mastery learning theory and behaviorist theory of reinforcement. Computer-based learning tailors the instruction to the individual needs of the student while striving to attain mastery of the content being taught. A separate variable framing this study is the concept of motivation, and especially self-efficacy theory. Understanding the foundations of the above theories implies a comprehension of the complexity of this research study on the impact of ITS systems on the achievement, self-efficacy, engagement and attitudes of Geometry students.

ITS and cognitivism. Some basic tenants of ITS are also anchored in cognitivist theory. In the late 1950's scientists began to minimize a concern with observable behavior and stressed instead more complex cognitive processes such as thinking, problem solving and concept formation (Ertmer & Newby, 2013). Cognitivist theory acknowledges the importance of the activities occurring inside the human mind. Whereas behaviorism treats the mind as a black box, cognitivism seeks to understand what is inside the black box, viewing the mind as a computer (Harasim, 2012). Just like the computer is an information processor, treating the human mind as a computer investigates how the mind receives input, processes, and then delivers output. Cognitive theories address the issues of how information is received by the learner, organized, stored, and then retrieved by the mind (Ertmer & Newby, 2013).

At the heart of cognitivism is Cognitive Information Processing (CIP) theory which discusses the mechanisms through which learning occurs. Atkinson and Shiffrin (1968) described a processing model that claimed that information received undergoes a series of transformations until it is permanently stored in memory. This multi-store model of memory consists of a sensory register, short term memory and long term memory and moves from store to store in a linear fashion (Atkinson & Shiffrin, 1968). As the learner attempts to learn new concepts, they are held in short term memory until the content is processed to move to long term memory (Driscoll, 2005). These permanent, structural features of the memory system enable for learning to take place. Cognitivism holds that learning occurs when information is stored in memory in a meaningful manner and forgetting is attributed to the inability to retrieve information due to interference, memory loss, or missing cues to help access previous content (Ertmer & Newby, 2013).

ITS systems utilize cognitive information processing theory as an anchor for the learning that takes place. Advocates of the CIP theory investigate how the environment modifies human behavior but specifically view the processing system of the learner as the intervening variable between environment and behavior (Driscoll, 2005). Processes under the voluntary control of the learner such as rehearsal, coding, and search strategies are a pervasive and integral component of human memory (Atkinson & Shiffrin, 1968). Cognitive Information Processing places a great emphasis in the active involvement of the learner in the learning process while supporting a learning environment that encourages students to make connections with material that has previously been learned (Ertmer & Newby, 2013).

Computer Based Instruction, and specifically ITS, is an area where the integration of cognitive theories is used. Computer Based Instruction presents the content in many different forms and aims to tutor and drill students, diagnoses learning difficulties while prescribing remedies for problems, and keep records of student progress (Kulik, 1982). Knowledge, in turn, is conceived through the creative intelligence of the learner and through the synthesis of information being received as it connects with the learner's prior knowledge. "Instruction must be based on a student's existing mental structures, or schema, to be effective" (Ertmer & Newby, 2013, pp. 53-54). When utilizing ITS systems, this feedback is generated by the computer program replicating the thinking of a human mind. Cognitivists make use of feedback to guide and support accurate mental connections (Ertmer & Newby, 2013). The software is in charge of corrective instruction in the cases where the student isn't being successful (Kulik, 1982). Intelligent Tutoring Software (ITS) systems are founded upon the principle that instruction is individualized and the computer system dictates what each student needs to learn. Students in turn have to reason through what they know and make connections in order to create new knowledge.

Mastery learning theory. Mastery learning activates the most powerful components of individualized instruction in order to improve student learning. Stemming from the work of Benjamin S. Bloom (1968), mastery learning theory claims that if teachers could provide the necessary learning time and learning conditions all students could reach high levels of achievement despite variant background knowledge. The premise of mastery learning is the utilization of small units of instruction and repetitive testing over the units enhances the learning experience as students need to exemplify mastery before moving on to new material (Bloom, 1968). A big part of mastery learning involves students working through learning the content that they have not yet mastered, or, students who are advanced are working on enrichment activities that extend upon the learning that has occurred.

One facet of CBI includes ITS systems, which are programs that maneuver through content by providing immediate and constructive feedback to the learner during when learning takes place. Intelligent tutoring systems fully employ mastery learning principles as they guide the student through knowledge acquisition (Anderson, Corbett, Koedinger & Pelletier, 1995). The content is broken up into chunks where the students master one area prior to moving on to another. The software is in charge of corrective instruction in the cases where the student isn't being successful; similarly, the software crafts enhancement activities or promotes students to new units of learning if they show mastery of a unit (Kulik, 1982). The purpose of any assessments administered throughout the content is to pinpoint areas of weakness in order to help the student move forward.

Behaviorism. Behaviorism is a learning theory that influenced many aspects of education today. Grounded in B.F. Skinner's (1958) theory that "behavior is shown to be shaped and maintained by its reinforcing consequences rather than has elicited as conditioned or unconditioned response to stimuli" (p. 972). In the behaviorist paradigm, learning is best facilitated through the reinforcement of an association between a particular stimulus and a response (Naismith et al., 2004). Therefore, learning according to behaviorist theory occurs by doing, from experience, and by trial and error. According to Skinner (1958), learning with technology could be implemented for a more precise, efficient facilitation of reinforcement in teaching.

Behaviorist theory is transparent when discussed in the context of technology in education. Rapid acquisition of basic concepts and skills calls for structured, deductive, and sequenced instruction (Morrison & Lowther, 2002). Computer assisted learning is governed by the behaviorist principles of obtaining certain learning goals through shaping, chaining, modeling, and punishment and reward. The drill-and-practice of certain content is coupled with the immediate reinforcement that technology offers. The behaviorist theory, in turn, affirms a close connection between how instructional methods can produce learning.

Self-efficacy. Self-efficacy is a framework used to explain motivation, which can further describe why learning occurs. Bandura (1977) defines self-efficacy as the beliefs that a person hold about their own abilities to perform a task. These personal convictions influence the level of effort people expend, their persistence when working through challenges, and their resilience in the event that they are not successful. The strength of people's faith in their own effectiveness impacts their decision to cope with given situations (Bandura, 1977). Pintrich (2003) defines self-efficacy as a student's belief in their ability to complete a task. There exist four major influences on self-efficacy beliefs, which include mastery experiences, verbal persuasion, vicarious experiences, and physiological arousal; the most powerful of these is mastery experience (Bandura, 1977).

A student's self-efficacy may have a direct impact on a student's achievement. A student's self-efficacy what they do, how hard they try, and how long they persist, while motivation is enhanced when students are perceived they are making progress is learning (Schunk, 1991). Self-efficacy is enhanced by how students interpret performance feedback, and students tend to work harder and longer when they judge themselves as capable of performing a given task (Mayer, 2008). Students with high levels of self-efficacy engage themselves in more thorough processing of the material during learning which consequently results to better understanding of the material (Mayer, 2008). Students are therefore more apt to perform better in achievement tests, which measure for understanding.

Self-efficacy plays a key role in mathematics education. Bandura (1997) defines mathematics self-efficacy as one's beliefs or perceptions with respect to their abilities in mathematics. Mathematics self-efficacy is a student's confidence in being able to solve mathematics problems. The influence of self-efficacy on his/her ability to solve mathematics problems played an equally pivotal role as a student's mental ability (Pajares & Kranzler, 1995). It is as important for students to believe that they can accomplish a task, as this mentality leads to persevering in solving mathematics problems.

Historical Perspectives

Computer literacy has been a part of our education system for four decades and has reshaped the delivery of instruction in many areas. Desktops computers were introduced into our classrooms in the 1980s through the Apple Classrooms of Tomorrow (ACOT) program, providing computer access for 1:1 teachers and students for the first time (Donovan, Hartley, & Strudler, 2007). The goal of ACOT was to promote change in the context of education. In the 1990s, through the Anytime Anywhere Learning program, Microsoft established a foundation for future 1:1 computing programs in the classrooms. Some of the benefits of the AAL program include an increase in enthusiasm for teaching and learning with technology, an improvement in student writing skills, an increase of authentic and purposeful use of technology, and a shift towards constructivist pedagogies (Donovan et el., 2007).

In 1989, the National Council of Teachers in Mathematics (NCTM) restructured the standards mandating the infusion of technology in the mathematics classroom. Aiming to keep American students competitive in the technological world arena, President Bill Clinton provided an education reform framework commonly, known as Goals 2000: Educate America Act (Goals 2000). Part C of Goals 2000, Leadership in Educational Technology, aims to address the need for the Department of Education to develop a national strategy to infuse technology into all educational programs and promote awareness of the potential of technology to improve teaching and learning. Some other goals of Educate America Act (Goals 2000) include to support state and local efforts to increase effective uses of technology in education and demonstrate ways that technology can be used to ensure all students have an equal opportunity to meet state education requirements (Goals 2000).

The integration of technology has evolved our education system way beyond what Steve Jobs and Steve Wozniak could imagine when they designed the Apple II computer in the 1970s. Technology has become key in enhancing how learning takes place and how curriculum frames the learning that occurs (Borne, 2003). Our students have never lived in a world without computers and they have access to knowledge 24 hours a day via the internet. They have no fear of technology and are not strangers to the digital learning world. They form the Generation C: connected, communicating, content-centric, computerized, community-oriented, and continually clicking (Friedrich, Peterson, & Koster, 2011). This generation is well connected via technology, they use social media and share everything created and learned. They are not categorized by a timeframe but rather by a mindset that is digitally focused; the only reality they have known is one facilitated by the internet and mobile devices (Friedrich et al., 2011). “Time is at a premium for Generation C, and they like to have instant, on-demand access to their content wherever they go” (Dye, 2007, p. 42). Using technology to learn, therefore, only makes sense for the generation of students that we teach, as they have never known a world without it.

Technology in the Mathematics Classroom

The integration of technology in the mathematics classroom can have a significant effect on enhancing student learning and helping students learn complex cognitive skills (Waalkens, Aleven & Taatgen, 2013). Although various types of learning technologies are present in our classrooms, effective technology integration is directly linked to curriculum and individual student needs rather than the specific technologies used (Harris et al., 2010). The benefits of technology infused instruction in the mathematics classroom spread to the teachers and the students alike. “Pioneers in Computer Based Instruction believed from the start that the computer would bring students great benefits, such as better, more comfortable, and faster learning; opportunities to work with vastly richer materials and more sophisticated problems; personalized tutoring and automatic measurement of progress” (Kulik, 1982, p.19). Technology benefits teachers as well, as technology is inherently able to meet the variant instructional levels of the students (Kleber, 2015). The ability of technology in aiding teachers in the capacity of differentiating teaching and learning for today’s students is pivotal to the success of the 21st Century classroom (Kleber, 2015).

Technology integration can impact student learning in various ways. This section gives an overview of Intelligent Tutoring Software systems while conveying the benefits of technology integration in the classroom. In addition, this section will reveal an overview of ALEKS, a particular type of Intelligent Tutoring Software, and encapsulate the foundations of ALEKS in Knowledge Space Theory while illustrating how learning and assessment look while using ALEKS.

Intelligent Tutoring Software (ITS). An Intelligent Tutoring Software (ITS) is a computer software system with problem solving capabilities imitating a human tutor (Anderson, Boyle, & Reiser, 1985). ITS systems can identify students' current knowledge and skills in efforts to help fill in gaps through its ability to interpret complex student responses as they offer guidance in helping the student understand the material. ITS systems provide immediate feedback and guidance to the learner thus meeting their individual needs in a timely fashion (Anderson et al., 1995).

ITS systems are not only adaptive to student needs but also can be very informative in helping the teacher make instructional decisions. Interactive, adaptive software programs use student data to inform teachers on individual and class progress. Adaptive software programs can assist teachers in the decision-making process (Foughty & Keller, 2011).

Benefits of technology integration. Technology integration impacts the instructional setting in the secondary level in various ways. Schacter (1999) conducted a large scale meta-analysis study reviewing over 700 empirical studies investigating the impact of technology on student achievement. Studies show that students learn more content in a less amount of time when they receive computer-based instruction (Schacter, 1999). Students showed positive gains in achievement on researcher constructed tests, standardized tests, and national tests and developed more positive attitudes and better self-concept when their classes include computer-based instruction. Results showed that use of intentional computer supported learning environment maximizes student reflection and encourages progressive thought and independent thinking. Lastly, the level of effectiveness of educational technology is influenced by the specific student population, the software design, the educator's role, and the level of student's access to the technology (Schacter, 1999).

Technology implementation in the middle school setting can have positive impacts on student achievement. One study investigated the impact of an online tutoring program on the achievement of struggling middle school students (Chappell, Arnold, Nunnery & Grant, 2015). One hundred nineteen students in grades six, seven and eight attended online tutoring sessions that averaged 37 minutes a day, twice a week, for 20 weeks. The program used was Focus EduVation (FEV), a program whose services utilized interactive tutoring. Students in both schools showed a significant improvement in achievement as measured by the Virginia SOL scores (Chappell et al., 2015). Overall, students had overwhelmingly more positive than negative comments about the use of online tutoring, highlighting positive learning outcomes for the tutoring sessions. "Online mathematics tutoring that embeds consistent progress monitoring may engage students in thinking about their own mathematics learning as a process for enhancing achievement" (Chappell et al., 2015, p. 47).

Intelligent tutoring software systems have the additional potential to affect the attitude of students. Motivation and learning outcomes can be improved by making content delivery more adaptive (Ostrow, 2015). One of the challenges teachers face is the multitude of levels present in the classroom. Observations revealed that mixing skill content can be beneficial in adaptive learning environments and appears to be especially significant for low performing students (Ostrow, 2015).

ALEKS overview. Assessment in LEarning and Knowledge Spaces (ALEKS) is a perfect example of an ITS system, and is widely used in teaching and learning of math across many K-12 school districts and higher education institutions. ALEKS is an online-based software system that uses an artificial intelligence engine to continuously assess the individual needs of the learner. The ALEKS website (2017) claims that the software will help increase student retention, grades, and performance on test scores. Through adaptive open-ended questioning, the software program knows exactly what a student knows and doesn't know in a course (ALEKS, 2017). ALEKS gives the student a choice of topics that they can learn, but they are limited only to the topics that the artificial intelligence engine has determined they are 'ready to learn'. Periodic assessments are generated for the student, in order to ensure that the student retains those topics that he/she learned.

Development and foundations in Knowledge Space Theory (KST). ALEKS developed from research at New York University and the University of California, Irvine, by a team of software engineers, mathematicians, and cognitive scientists with the support of a multi-million dollar grant from the National Science Foundation (ALEKS Corporation, 2017). The theoretical basis for ALEKS lies within the mathematical cognitive science known as Knowledge Space Theory (ALEKS Corporation, 2017). Knowledge Space Theory (KST), is a set-theoretical framework, which proposes mathematical formalisms to operationalize knowledge structures in a particular domain

(Doignon & Falmagne, 1999; Falmagne et al., 1990). KST encompasses knowledge states, knowledge structures, and knowledge spaces. The knowledge state is determined by the set of questions that a learner is capable of answering correctly about a topic in ideal conditions (Doignon & Falmagne, 1999). Knowledge structures are representations of knowledge states, and are only partial schemata of a skill set (Doignon & Falmagne, 1999). Knowledge structures are often referred to as learning pathways. Knowledge spaces, in turn, consist of all the knowledge needed in order to understand a concept; they are created as learning pathways develop more connections between subject matter and prior knowledge. Doignon and Falmagne (1999) assert that an artificially intelligent adaptive assessment creates two categories of problems that guide students and teachers: what each student can do and what he/she is ready to learn. These two categories of problems uncover the complete knowledge state of the learner (Doignon and Falmagne, 1999).

The application of Knowledge Space Theory can have a significant impact on how students learn. KST has been found as a valuable quantitative assessment method for evaluating and suggesting the most feasible learning pathways taken by students (Taageperaa, Pottera & Millera, 1997). KST is a useful tool for revealing various aspects of students' cognitive structure and can therefore be used as an assessment tool or as a pedagogical tool to address various issues regarding student-learning (Arasasingham, Taagepera, Potter & Lonjers, 2005). The periodical assessments created by the software can be utilized pedagogically as formative tools to help identify students' weakness and shape the students' next learning focus. Similarly, these computer-generated assessments can be also utilized as summative assessments where student grades are recorded for evaluative purposes.

How does learning look using ALEKS? All students using ALEKS have to take an initial assessment of approximately 25 questions. All questions are based on students' answers to previous questions, allowing ALEKS to determine a student's previous knowledge and potential areas for growth. It is through this individualized initial assessment that ALEKS uses Knowledge Space Theory to determine which topics a student knows, does not know, and also which topics a student is ready to learn (ALEKS, 2017). At the end of this assessment, a student is provided with a colorful pie chart of topics that they are ready to learn and can chose from during any point in time during interacting with the software. Each sector of the chart corresponds to a particular area of content. A student is considered to be in 'learning mode' anytime they enter the pie chart and choose a topic to work on. Instruction can be in different formats, including text, audio, simulation or video.

When a student chooses a topic, he/she is provided with foundational concepts, examples, and practice problems in order to gain understanding. Presented only with open-ended problems, a student is also provided with an 'explain' button that shows the step-by-step mathematical process in solving a problem, along with additional examples for the student to practice. The student receives immediate feedback, suggestions for correcting mistakes or direction to consult the ALEKS on-line dictionary for fundamental definitions. Once a student has consistently entered the correct answer for several consecutive questions (typically about 3, but varies depending on the topic), ALEKS considers a student to have mastered that topic, meaning that the student is now ready to select new, higher-level topics to work on. If a student answers questions incorrectly on topics that have been 'mastered' during an assessment, then the topic is added back to the pie chart as one that the student is ready to learn and can therefore practice even more.

***Assessment using ALEKS*.** After a student has mastered several topics, ALEKS generates an assessment on newly and previously mastered topics, as well as new topics that a student hasn't seen yet. ALEKS assessments are always an open-ended, and they periodically present questions on topics that have been mastered weeks, even months before. ALEKS does not use multiple choice questions on assessments, as the program wants the student to enter all answers in electronically mimicking much of what it's like writing an answer on paper.

Upon the completion of an assessment, a student is taken back into the learning mode, where they can once again access the pie chart that contains all the course topics. If it is determined that a student no longer has mastery of a topic, then it gets placed back in the pie chart as a topic that he/she is ready to learn (or relearn in most cases). The teacher can instantly see data on student assessments as well as view the working history as they work through mastering the objectives. In addition, the teacher can view how long a student has spent on an assessment and in learning or mastering each particular topic.

So ALEKS uses this careful categorization of mathematical topics into knowledge spaces in order to assess the knowledge state of a learner and work towards mastery of topics. Through accessing and expanding only on the topics that a student is ready to learn, ALEKS can potentially impact student learning and motivation through adapting instruction in order to meet each student's individual needs.

Current Research on ALEKS

ALEKS has helped students make academic gains in mathematics in the K-12 setting as well as in the post-secondary environment (Hagerty and Smith, 2005; Huang, Craig, Xie,, Graesser & Hu, 2016; Yilmaz, 2017; Nwaogu, 2012) . The research cited below is not intended to be an all-inclusive list of previous studies but rather is intended to narrate what has been completed as well as to demonstrate a gap where further research is necessary. Furthermore, the aim is to focus only in secondary and post-secondary studies since the purpose of this current study is to investigate the impact of ALEKS on high school geometry students.

It is important to note that the research below is framed around demonstrating the effects of ALEKS on both academic achievement and motivation of mathematics students. In the subsequent section, research studies have been summarized and synthesized in order to show positive results of ALEKS when used during school on student achievement, self-efficacy, attitudes and engagement. In addition, a discussion is included on studies utilizing ALEKS in the after-school setting, studies showing non-positive results, and challenges with using the ALEKS software.

Positive results of ALEKS use on student achievement. The effect of ALEKS on math achievement and its impact on closing the achievement gap in math performance of middle school students was investigated in a study involving 1,110 students in grades five through nine (Yilmaz, 2017). In a quantitative quasi-experimental study involving two different public school charter districts, students were divided in either the control or the treatment group; the experimental group worked about 45 minutes per day making progress on their individual learning paths. Achievement was measured by comparing the students' fall and spring MAP scores and further analysis was performed through examining the time students spent using the software. ALEKS was found to have a positive effect in student achievement across all grade levels (six through nine), across both gender groups, all racial/ethnic groups (African American, Hispanic, and White), and all special programs (Special Education, Limited English Proficient, Gifted/Talented, and Economically Disadvantaged) (Yilmaz, 2017).

Intelligent tutoring software such as ALEKS carry the potential of helping students across grade levels regarding the variant levels of mathematical ability. Fine, Duggan & Braddy (2009) examined the effect of ALEKS on 12th grade mathematics students who had a score of 18 or lower on the mathematics portion of the ACT test. Students were enrolled in ATLAS, a mathematics class that also provided in and out of class time for students to utilize ALEKS. Seven of the 32 students enrolled in ATLAS with ALEKS increased their ACT mathematics score to at least 19, and 19 of the 32 students increased their ACT mathematics score by at least one point; the above statistics point that ALEKS was successful in helping students raise their ACT scores (Fine et al., 2009).

The fact that students have access to ALEKS software during the school day and even after the school day ends can be very beneficial to their learning. A research study by Stillson and Alsup (2003) found that students who spent more time on ALEKS had better overall grades and performed better on assessments. Considering it is challenging to find that extra time during the school day, ALEKS can be a very powerful resource in that students have access to the content and their learning path 24 hours per day given they have access to the internet (Stillson & Alsup, 2003).

When used in a college mathematics Level I class, ALEKS had a significant effect on students' mathematics achievement (Nwaogu, 2012). In quasi-experimental one-group nonrandomized pretest and posttest design, the author tests the effects of ALEKS when using only an online implementation environment over the course of two academic semesters. Students showed gains on mathematics achievement as operationally defined by weekly quizzes and posttest, all generated by ALEKS (Nwaogu, 2012).

So when utilized within the instructional day, ALEKS has the potential to help students improve their mathematics performance in the high school courses and in the standardized tests that administered throughout the school year.

Results of ALEKS use on student attitudes and self-efficacy. Intelligent Tutoring Software such as ALEKS can help increase the mathematics knowledge and motivation of high school students. In a qualitative study researching the effects of ALEKS on ninth and 10^{th}-grade students, Schnoebelen (2008) used student interviews to determine the effects of ALEKS on 32 high school students who were all considered not proficient in mathematics as eighth-grade students. The interviews aimed at gaining student perspectives on what they like and dislike about ALEKS, the reason why their math scores changed from eighth grade to ninth grade and from ninth grade to 10^{th} grade; in addition, students were asked questions on whether or not ALEKS made a difference on their Iowa Test of Educational Development (ITED) scores. The results of the study showed that ALEKS helped the mathematics performance of some students and their individual math skills (Schnoebelen, 2008). The evidence suggests that ALEKS was a valuable use of instructional time as the majority of the students said that the computerized instruction helped them learn, review, and improve their math skills (Schnoebelen, 2008).

In a quasi-experimental research study involving a convenience sample of 81 students, Wendel (2016) examined how ALEKS and My Math Lab (another tutoring software) affected student achievement in addition to student anxiety, self-efficacy, and attitude towards learning. All students were enrolled in a remedial mathematics course in a public state college in Florida. When comparing the results, students who had completed their work in ALEKS had higher attitudes, higher self-efficacy and better academic achievement than students who had completed their work on the My Math Lab software.

Additional studies point to the effects of ALEKS on student attitudes towards mathematics. Taylor (2008) examined the academic performance and student anxiety and attitudes of 54 ALEKS users to 39 traditional lecture students in an intermediate algebra course. The student population sample came from three colleges and two universities. The data collected showed no statistically significant difference in academic performance between the two groups of ALEKS users and traditional learning students. Despite those findings, ALEKS users did show a decrease in anxiety and an increase in attitudes toward mathematics when compared to traditional students.

Positive results of ALEKS use in after-school settings. Low performing students require help after school in order to catch up to their peers or not fall farther behind. One study explored the effect of ALEKS on reducing achievement gaps in mathematics when used in an after-school setting (Huang et al., 2016). The subjects were 533 sixth grade students from five middle schools in West Tennessee. Participants were randomly assigned in two conditions, one that utilized ALEKS as an instructional method and one that employed teacher-led instruction only. The study finds that intelligent technology software such as ALEKS can benefit disadvantaged populations such as low socioeconomic status, girls, and African Americans (Huang et al., 2016). In addition, students that were in the ALEKS sections showed post-program academic gains of the same level whereas students in the teacher-led sections had varied performance level on the Tennessee Comprehensive Assessment Program (TCAP), likely because they came from different gender, races/ethnicities, or school-SES (Huang et al., 2016). Students of different races/ethnicities and genders did not differ on math achievement after using educational technology, mostly due to the ability of an ITS program such as ALEKS to capture individual differences and distribute content tailored to meeting the unique needs of the learner (Huang et al., 2016).

ALEKS software has been implemented in after-school programs and as a supplemental homework component. Hagerty and Smith (2005) used ALEKS to replace traditional homework assignments in a college algebra course involving 251 students. These students were randomly assigned to a section that used ALEKS (the experimental group) or a section taught in a traditional manner (the control group). Results showed that three of the four ALEKS sections dramatically outperformed the control groups in gains between the pretest and the posttest, and the one section that was the exception was the only night section using ALEKS.

Another study measured the effects of using ALEKS in an after school setting in improving mathematical skills of struggling students (Craig, Hu, Graesser, Bargagliotti, Sterbinsky, Cheney & Okwumabua, 2013). The participants were 253 sixth grade students from four middle schools in a school district in Tennessee. In each school, there were four classes: two ALEKS and two control with one teacher in charge of each class made up of no more than 20 students. The program was held after school for two hours twice a week, and an assessment was given every fifth time the class met. The researchers used the results of the Tennessee Comprehensive Assessment Program (TCAP) in order to measure academic achievement. Students assigned to the ALEKS classrooms performed at the same level as students taught by expert teachers on the TCAP. Although scores were higher in the ALEKS treatment group, they were not statistically significant. Students' conduct and involvement remained at the same level in both conditions as well. Students assigned to the ALEKS classrooms, however, required far less assistance in mathematics from teachers in order to complete their work.

So ALEKS software can aid the student inside and outside the actual classroom time while providing the support that they need with instruction that is tailored to their individual needs. This can help students in after-school programs, while completing homework, or just as another tool to have at their disposal that can enhance their academic foundations.

Studies with non-positive results on utilization of ALEKS. Not all studies show positive gains in achievement through when utilizing ALEKS software. In a quantitative study by Grienier (2013), the effect of ALEKS software on student achievement was measured employing a quasi-experimental pre-test and post-test design using NWEA Measures of Academic Progress (MAP) test. Students were divided into two groups where Group A did not work with the ALEKS software program and Group B worked with the ALEKS software program once a week. All students completed a

MAP program pre-test at the onset of the study. After a nine week period of implementation of ALEKS with the experimental group, both groups took a post-test and results were analyzed within and between groups controlling the pretest. Results showed that ALEKS had no significant effect on mathematics achievement when comparing the results of the pre- and post- assessment MAP data (Grenier, 2013).

In another middle school study, Mertes (2013) investigated the effect of ALEKS on student achievement based on district created assessments as well as state standardized test scores at the middle school level. There were six sections (class of approximately 30 students) of each grade level with five direct instruction courses and one ALEKS course. The ALEKS instruction experimental group included 65 students, and the direct instruction control group included 283 students. Direct instruction students significantly outperformed ALEKS students in grades six and eight on the district-developed concept tests, while seventh grade students show no significant difference in scores (Mertes, 2013). When comparing test scores of the Minnesota Comprehensive Assessment (MCA-III) between the two groups, students in the ALEKS and direct instruction class showed no statistically significant difference in achievement (Mertes, 2013).

So not all studies that utilize ALEKS point to positive results, but the individualized instruction and feedback that is generated by the software can still positively impact the learning experiences of high school students. The artificial intelligence that powers the software can help students identify and fill mathematical gaps through targeted instruction and assessment methods.

Challenges with using the software. There exist multidimensional challenges with implementing ALEKS software in the classroom including financial cost, time constraints, student and teacher frustration regarding technology implementation and specifically artificial intelligence software. In order to fully implement ALEKS, an individual license has to be purchased for all students, which in a large school that can amount to thousands of dollars. Intelligent Tutoring Systems such as ALEKS are expensive to develop and even more expensive to maintain in order to stay current within the technological environment (Hrubik-Vulanovic, 2013).

Finding additional time to use the technology during class is an additional challenge, as instructional time is at an already high premium. A research study by Stillson and Alsup (2003) stated there was a direct correlation between the time spent on ALEKS and academic achievement, yet finding the time to spend on ALEKS during the school day remains a challenge. Yet on the contrary, another study shows there is no direct correlation between time spent using the software and the mastery of mathematical concepts (Nwaogu, 2012). So the concept of how much time to spend utilizing the software presents a challenge within itself.

Lastly, the fact that the software takes a student back to a concept that has previously been mastered is a unique challenge that students who do not particularly retain concepts tend to have to repeat that instruction and practice on the particular topics. When asked about the various aspects of the online system, students expressed frustration over having to review materials that have already been mastered and over the fact that they were not able to review the problems missed during a recent assessment (Stillson & Nag, 2009). It is possible that students grow increasingly resentful of the fact that they learned and mastered a topic yet after an assessment shows lack of retention of that topic, they are then forced to review and work out even more problems.

Other indicators that pointed to reasons why students failed in a remedial college level Algebra course incorporating ALEKS point to lack of motivation, intimidation of technology, and a general lack of good study skills contributed to approximately 41% of the students failing the course (Stillson & Nag, 2009). College students in remedial mathematics classes stated that they enjoyed going to lecture and practicing mathematics problems related to the lecture material (Stillson & Nag, 2009).

So the use of ALEKS software can have an overall powerful effect on student achievement and motivation through the individualized method of instructional delivery. Since the software is web-based, it allows students access to their learning during and after the school day hours. Although challenges exist, implementation of ALEKS software can have a positive impact in the secondary and post-secondary classroom.

Potential Impact on Achievement High School Mathematics

Technology is becoming increasingly important in impacting mathematics education. Differentiated learning and the various methods of content delivery are only some of the ways that artificial intelligence technology continues to make forward strides in the future of mathematics. "Teachers say one of the biggest benefits they've seen from the use of the technology is that students' confidence levels and their ability to truly understand and explain the math they're doing have risen" (Davis, 2011, p. 38). Another way intelligent tutoring software technology is helping teachers is that it grades student work and provides feedback instantly, thus keeping the paperwork turned in to the teacher to a minimum (Stillson & Nag, 2009). Whether it is ALEKS, or one of the many other programs that use technology in delivering and assessing instruction, technology is impacting the future of mathematics (Davis, 2011).

Implementing intelligent tutoring systems in the high school mathematics classes can aid in increasing student motivation. One way is through allowing a student to have a choice of the assignment he/she plans to study, as choice is an intrinsically motivating force as a student feels that what they have chosen to study has high importance (Ostrow, 2015). In addition, the feedback given by an intelligent software system can help impact learning outcomes through fostering a growth mindset, thus motivating the learner (Ostrow, 2015).

Potential impact on closing the achievement gap. ALEKS has the potential of narrowing and eventually closing the achievement gap in mathematics. The female drop-out in STEM fields can be explained or ameliorated through controlling the choice of assignment that an intelligent software system may allow (Ostrow, 2015). In a study conducted by Yilmaz (2017), results showed that each treatment group participating in mathematics instruction incorporating ALEKS outperformed the control group across all grade levels (6 through 9), both gender groups, all racial/ethnic groups (African American, Hispanic, and White), and all special programs (Special Education, Limited English Proficient, Gifted/Talented, and Economically Disadvantaged) in spring NWEA MAP mathematics assessment.

The current action research study. The current research study collected both quantitative data (in the form of content assessments, surveys) and qualitative data (in the form field notes, daily student questionnaires, and focus group interviews) in order to deepen the understandings of the inquiry. The current research explored the effects on ALEKS when utilized within the typical academic block. An additional advantage at Achieve High School is that it is an one-to-one school, where all students have a personal

Chromebook device assigned to them for the duration of the year, making implementation of a web-based software program a lot easier.

Summary

The purpose of this research study is to examine the effects of ALEKS, an Intelligent Tutoring Software (ITS) program, has on student achievement, self-efficacy, engagement and attitudes towards mathematics. This literature review provided a synopsis of the theories that frame computer based learning. Two major theories that support this study are cognitivism and behaviorism. Certain behaviorist principles that aim at obtaining learning goals through shaping, chaining, modeling, and punishment and reward help frame the theory behind computer-based instruction. In addition, mastery learning theory also helps ground computer-based instruction, as it helps a student work towards mastery of concepts through continuous repetition and practice that occurs at the individualized level of the student. These theories form together to frame part of the theoretical foundations for this Action Research study.

This study will contribute to the literature by investigating the effects of ALEKS on achievement, self-efficacy, attitudes and student engagement when implementing the software during the academic school day. Our education system has been impacted through the evolution of technology, and ITS systems can further impact the delivery and application of mathematical content. ALEKS software has the potential of helping students become independent problem solvers while growing accustomed to an online delivery method of content. Lastly, ALEKS has the ability to meet the student at their current ability level while it helps them develop further as students and as mathematicians.

Section 3 of this Action Research study will provide an in depth examination of the research design, role of the researcher, research questions, as well as ethics in the research process. Section 4 of this study will reveal the results of the quantitative and qualitative data that is collected. Section 5 will discuss the results, examine implications for educational practice, and establish recommendations for future studies.

CHAPTER 3

METHODOLOGY

This chapter will provide a thorough synopsis of the research methodology that will be utilized in order to answer the research question. The purpose of this action research is to explore the impact that incorporating ALEKS, an Intelligent Tutoring Software (ITS) system, has on student achievement, self-efficacy, engagement and attitudes towards mathematics at Achieve High School. At the heart of the purpose of this research is the school-wide problem of practice of low mathematical achievement as evidenced by low EOC scores, which further points out that the majority of our students are struggling to retain the mathematics that we teach them in our classroom. Although the focus and analysis of this study is narrowed to geometry students, this action research model can be applied to mathematics courses across the mathematics department as many teachers voice concern about poor student achievement in Algebra 1, Algebra 2 and pre-calculus courses.

Action teacher encourages teachers to become continuous, lifelong learners in their classrooms with respect to their practice (Mertler, 2014). It is applicable to the individualized needs of the educators and their practice. Action research combines action (or an intervention aimed to improve existing practices) and research by employing iterative, spiraling steps of planning, acting, observing, reflecting, and planning again (Burns, 2005). This chapter presents the research methodology used in this study in order to find out how ALEKS impacts mathematics achievement, self-efficacy, engagement, and student attitudes towards mathematics within the parameters of a sample 11th grade geometry student population.

Intelligent Tutoring Software (ITS) is reshaping the dynamics of the classroom through differentiating instruction by responding to individual student needs. While millions of dollars are spent each year in the United States on providing technology for our students, we as teachers need to ensure that the technology integration lends to meaningful learning experiences and academic growth for our particular students. Research indicates that technology can impact student achievement in six ways (Smith & Thorne, 2007). Three of these ways germane to this research include when the application supports curriculum objectives, when technology is integrated during the school day, and when the application adjusts for student ability and provides feedback to all parties about performance and progress (Smith & Thorne, 2007).

Action Research

Action research is a rigorous, systematic method to pursue answers to problems that are present in our classrooms and is anchored within principles of cyclical reflection. “The main goal of action research is to address local-level problems with the anticipation of finding immediate solutions” (Mertler, 2014, p. 12). Action research allows teachers to study their own classrooms in order to better understand the complexity, implication, and possible solutions to a current and pertinent problem of practice. It is through cautious reflection and cyclical planning that the teacher focuses on the next steps of this continuing research process. Combined with the benefit of investigating a problem that is close to home, one of the major benefits of action research is that teachers are integral members of the research process, which makes them more likely to facilitate change based on the knowledge they create (Dana & Yendol-Hoppey, 2014).

Research Design

A mixed-methods convergent design was used to conduct this action research study (Creswell, 2012). This study utilizes a quasi-experimental design, which incorporates no random assignment of participants to groups and is best utilized when providing a description of what is happening in a particular setting or situation (Mertler, 2014). Implementing a two-group control group design ensures that while one group will be offered the treatment (implementation of the ITS system ALEKS) the other group will act as a control group. The teacher-researcher used students from her two geometry classes that are already intact as research subjects.

This study employed a pretest-posttest multiple group design comprised of two groups of geometry students in order to accurately measure and assess the effects ALEKS on mathematics achievement, self-efficacy, engagement and attitudes towards mathematics. All students were administered a content pretest at the onset of this research. The intervention (implementation of ALEKS software with the experimental group) spanned over two units of instruction, each lasting approximately three weeks. For the duration of the first unit, one of the geometry classes utilized ALEKS as part of their learning twice a week while the other geometry class was exposed to teacher-led, standards based lessons. At the end of the first unit, all students in both groups were administered a posttest. The process repeated for the second unit of instruction, where students in both the experimental and control group took the same pretest and posttest but the experimental group continued to utilize ALEKS as part of their learning for two hours a week. A pretest posttest control group design allowed for measuring the effect of a treatment and compare to the group not receiving the treatment. Furthermore, the teacher-researcher chose to go through two pre- and post- test cycles in order to ensure that the results are valid and any statistical changes noted are not accidental.

A convergent mixed-methods design combines both quantitative and qualitative data in efforts to better comprehend the dimensions of the research problem (Creswell, 2012). Using a mixed methods approach, this study provides numeric data that is statistically analyzed but also qualitative data that permits for in-depth exploration of the student population involved in this study. "The true benefit lies in the fact that the consideration of both types of data may provide a better understanding of the research problem than either type of data alone" (Mertler, 2014, p. 104). In a convergent mixed-method design, qualitative and quantitative data are gathered simultaneously but separately from each other, data is analyzed separately, and the results are compared (Creswell, 2012).

Research Site

Achieve High School is a rural high school of 1,374 students in the small rural town of Dreamtown, South Carolina. The school has a demographically diverse population with 1% Asian, 2% two or more races, 39% Caucasian, 8% Hispanic, and 49% African American (S.C. Department of Education, 2016). The poverty index of AHS is high with 70% of the students are receiving free/reduced lunch. The school has a student to teacher ratio 26:1 in core subject classes and 53% of its faculty members hold advance degrees (S.C. Department of Education, 2016). The school follows a 4 x 4 block schedule while the ninth-grade students belong in the ninth-grade academy and have year-long English, mathematics, and social studies classes that are 55 minutes in length.

All of the remainder of the classes are 90 minutes long and they meet 5 days a week for 90 days.

Research Sample

The participants of this study were 45 11th grade students enrolled in college preparatory geometry led by the teacher-researcher. The intervention group originally consisted of 29 students, but only twenty three students had permission to participate in the study (N=23). The control group initially had 28 students but only 22 students agreed to participate (N=22). This resulted into a convenience sample of 45 students that were divided in two separate classes. These classes represented an ethnically diverse group, where 23 students were African American, 12 were Caucasian, nine were Hispanic, and one was multi-racial. There were 19 males and 24 females. Seventy-one percent of students (N=32) were receiving free or reduced lunch at school (data retrieved from PowerSchool, 2018). There were only two students who understand minimal English (level 1 proficiency) and chose to work the ALEKS software in the Spanish language. Eight students had an Individualized Education Plan that addressed accommodations due to various learning disabilities.

The students came from various academic and social backgrounds. Sixty-four percent of students (N=29) made a D or a C in Algebra 1 and only 15 made a B or better (data retrieved from PowerSchool, 2018). Nearly a third of students (N=14) had a D or a C in Algebra 2. Nine students were repeating the Geometry course due to prior failure of low grades or due to attendance issues. Thirty-eight percent of the students (N=17) indicated they held a part-time job after school at various food service and retail establishments within 20 miles of the school. Fifty-five percent of the students came from single parent homes and 100% of the students indicated a desire to extend their education past high school into a four-year institution.

A focus group of seven students was selected from the 23 students in the intervention group in order to participate in a semi-structured interview aimed at deepening the understanding of student performance and personal perceptions. The participants were carefully selected in order to form a racially/ethnically diverse focus group of students. This is important in order for this research study to provide a holistic representation of the diverse perceptions present among the participants of this study. The seven students selected were Ethan, Oliver, Mylah, Sonia, Tara, Mason, and Alyssa (pseudonyms), and a short profile of each student is narrated below:

- Ethan is an African American male who is very inconsistent in his mathematics performance. He has a part-time job working for a local retail store and is very outspoken in class and with his peers. He does not like working independently and often helps his peers or receives help from other students in class.
- Oliver is a Caucasian male who plays the trumpet in the band. He used to be an honors student as a 7^{th} grader, but is no longer taking any honors classes. He is reserved as a student but enjoys working with technology. He almost always completes his homework.
- Mylah is an African American female who is a varsity cheerleader and has expressed interest in graduating early. Although she is consistently performs at a ‘B’ average, she does not like doing homework and it is often incomplete or missing.

- Sonia is a Hispanic female who stated that she does not like mathematics. She has moved twice since she started high school and has stated she is moving at the end of the year.
- Tara is an African American female who has also stated she does not like mathematics. She is a member of the step team and has voiced interest in studying dance in college.
- Mason is an African American male who struggles in mathematics. He typically performs below average in Geometry (has a D average) and has several disciplinary infractions as a junior. He is quiet as a student, and he hardly ever asks questions in class.
- Alyssa is a Caucasian female who works as a shift manager at a fast food restaurant in Dreamtown. She is very conscientious as a student but is very quiet and does not participate in class discussions or ask questions out loud in class. She has expressed interest in graduating a semester early and attending college classes during her second semester of her senior year.

The above students were selected based on their diverse ethnic backgrounds, unique personalities, and varying mathematical ability. By meeting the above selection criteria, these students were carefully chosen in order to represent the diversity present in the teacher-researcher's student participants.

Intervention

The intervention utilized in this study was ALEKS, an ITS system that is web-based and utilizes artificial intelligence in order to teach and assess pedagogical content. ALEKS uses adaptive questioning to quickly and accurately assess what a student knows and does not know in a course. When first logging onto ALEKS, the student is guided through a learning tutorial on how to maneuver through the software. Then the student is given an initial knowledge check in order to assess what the student currently knows. The software then instructs the student on the topics he/she is ready to learn, offering progress knowledge checks along the way.

The student's progress is shown in the form of a pie chart as shown below in Figure 1. This chart shows a summary of what topics a student has mastered and which ones are still remaining. At the heart of the pie chart is the number of topics that the student has mastered. The student can choose any topic to work on among the different 'pie pieces', but they can only work on topics that the software has derived they are 'ready to learn'. After spending several hours on the software, the student is prompted to take a progress knowledge check so that they can demonstrate mastery of the topics that they learned. If a student does not remember a certain topic and gets a question wrong in the knowledge check, then the software guides the student to learn that topic again by placing it in the group that he/she is 'ready to learn' again.

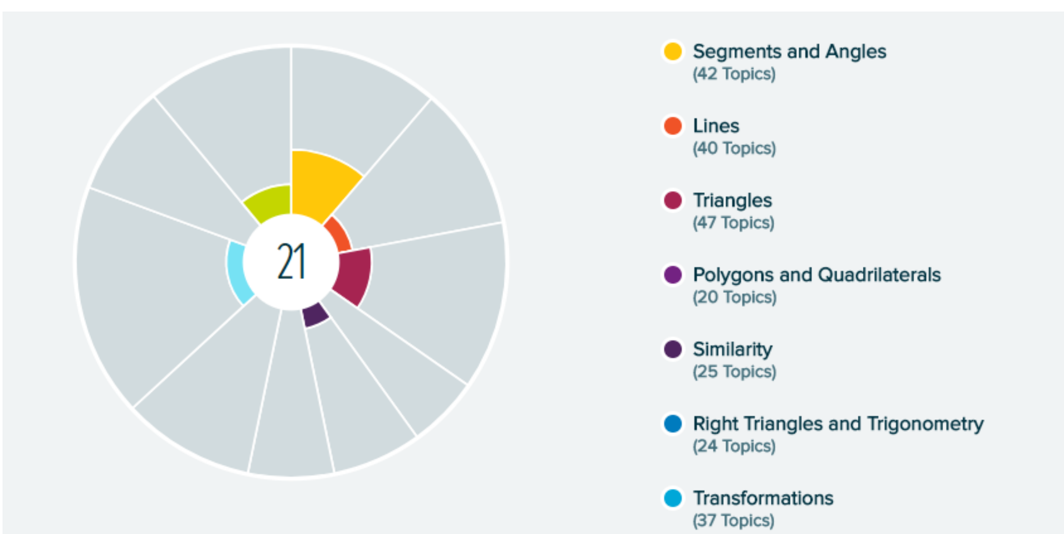


*Figure 3.1.*Sample ALEKS pie chart.

Data Collection

This study utilized numerous techniques that collected both qualitative and quantitative data. For the purpose of examining the effects of ITS systems on the achievement, self-efficacy, engagement and student attitudes towards mathematics of Geometry students, several methods of data collection were devised in order to triangulate the results. The data collection instruments included: (1) pretests and posttests of two instructional units (2) pre-research and post-research student self-efficacy surveys (3) pre-research and post-research student attitude surveys (4) daily student engagement questionnaires (5) researcher field notes and (6) focus group interviews. Table 3.1 below summarizes the types of data collected by each of these instruments and shows how these instruments are connected to each of the research questions of this study.

Table 3.1
Summary of Data Collection Instruments and how they relate to the research questions.

Research Question	Data Collection Instrument	Type of Data
1. What are the effects of ALEKS on 11th grade geometry students' skills of applying geometry theorems in mathematical contexts?	Pre- and post- tests of 2 units	Quantitative
2. What are the effects of ALEKS on self-efficacy on 11th grade geometry students?	Self-efficacy survey	Quantitative
	Focus group interview	Qualitative
3. What are the effects of ALEKS on student attitudes on 11th grade geometry students?	Student attitudes survey	Quantitative
	Focus group interview	Qualitative
4. What are the effects of ALEKS on student engagement on 11th grade geometry students?	Daily student engagement questionnaire	Quantitative
	Researcher field notes	Qualitative
	Focus group interview	Qualitative

While the quantitative data is more numerical and the qualitative data above is more narrative, the combination of data stated above helped deepen the understandings of this inquiry. The teacher-researcher aimed at increasing validity with the incorporation of a control group. Students in the control group completed the concept assessments, and student engagement questionnaires along with the students in the experimental group. Since only the students in the experimental group were exposed to the intervention (ALEKS software), the teacher-researcher was only interested in measuring the effects of ALEKS on the self-efficacy and attitudes of only those students.

Measuring achievement in mathematics. Achievement is a complex concept and can be operationalized in many ways for purposes of research. For purposes of this action research, mathematics achievement was measured based on the ability of students to apply geometry theorems in mathematical contexts. The growth between pre- and post-test on two summative unit assessments was measured and statistically analyzed. The unit assessments are included in Appendix F (Unit 1 assessment) and Appendix G (Unit 2 assessment). These assessments consisted of 32 questions that were relevant to the current unit of study and directly aligned with the South Carolina course standards for geometry. The standards included in these unit assessments are directly adapted from the South Carolina College and Career Standards for High School Geometry (SCDOE, 2015) and are listed below, stating that the student will be able to:

- Define angle, perpendicular line, parallel line, line segment, ray, circle, and skew in terms of the undefined notions of point, line, and plane. Use geometric figures to represent and describe real-world objects.

- Prove, and apply in mathematical and real-world contexts, theorems about lines and angles, including the following: a) vertical angles are congruent; b) when a transversal crosses parallel lines, alternate interior angles are congruent, alternate exterior angles are congruent, and consecutive interior angles are supplementary; c) any point on a perpendicular bisector of a line segment is equidistant from the endpoints of the segment; d) perpendicular lines form four right angles.
- Analyze slopes of lines to determine whether lines are parallel, perpendicular, or neither. Write the equation of a line passing through a given point that is parallel or perpendicular to a given line. Solve geometric and real-world problems involving lines and slope.
- Use the distance and midpoint formulas to determine distance and midpoint in a coordinate plane, as well as areas of triangles and rectangles, when given coordinates.

The broad goal is strengthening the mathematical foundations while increasing student achievement in geometry classes. Although this is beyond the time frame and scope of this action research, curriculum assessment scores along with report card data can provide a skeleton of how student achievement is impacted by intelligent tutoring software.

Measuring student self-efficacy. Self-efficacy is defined as the belief in one's ability to accomplish a given task, the self-perception one has of his/her competence (Bandura, 1997). The instrument used to measure self-efficacy is the mathematics self-efficacy questionnaire containing 18 5-point Likert type questions (See Appendix A). This was developed by the teacher-researcher by modifying an original mathematics self-efficacy and anxiety questionnaire that was written, pilot tested and used in a study by measuring student self-efficacy and anxiety towards mathematics (May, 2009). The original questionnaire was modified so that only items pertinent to self-efficacy are being measured. The mathematics self-efficacy questionnaire was pilot tested once prior to being used with the current action research. After that pilot testing, the teacher-researcher deleted 11 questions as they were not pertinent to the current study. The student answers range from 1(Never) to 5(Usually) (See Appendix A). Sample questions from this self-efficacy questionnaire are “I believe I can do the mathematics in this Geometry course” and “I have set goals in my mathematics classes”.

Pre- and post-research student attitude survey. The timeframe of this action research was set for six weeks in order to be able to collect all the appropriate data. At the onset of this study, the teacher-researcher administered a pre-research student attitude survey on the first day designed to measure attitudes about mathematics, school, and technology (see Appendix B). This survey was developed by Brookstein, Hegedus, Dalton, Moniz & Tapper (2011) in order to measure student attitudes and beliefs towards mathematics. Various analyses were conducted in order to assess the concurrent and predictive validity of the instrument. The student attitude survey was developed as part of a classroom project in a quasi-experimental intervention study involving the use of software technologies in a mathematics classroom (Brookstein et al., 2011).

The survey consisted of 27 items and participants of the study were asked to report the extent to which they agree or disagree to a statement on a scale of 0 (“Strongly Agree”) to 4 (“Strongly Disagree”) (see Appendix B). This survey was created on the hypothesis that student attitudes and beliefs would change over time and was intended to measure that change in student attitude as well as student comfort level with sharing their ideas in mathematics class (Brookstein et al., 2011). Students were administered the identical survey on the last day of the study and the teacher-researcher will analyze the results as to how they compare to the initial administration of the student attitude survey.

Daily student engagement questionnaires. Another point of data collection was daily student engagement questionnaires created by the teacher-researcher (Appendix C). This instrument was pilot tested with a group of geometry students in the spring of 2018 and the answers were found to be consistent with the observations of the teacher-researcher so no changes were made after this pilot testing. One of the ways to increase the validity of an instrument is to conduct a pilot test and further refine the contents of the instrument (Brookstein et al., 2011). The purpose of the data collected from the student engagement questionnaires was to help students reflect on how engaged they were in their own learning by answering the two Likert scale questions and the three open ended items as seen in Appendix C.

The focus of the questionnaire was to provide a participant view of the level of engagement and relevance of the content that the student worked on during a particular lesson. The first question asked students how they would rate themselves as being on task on a scale of 1 to 5 with 5 being the best. After pilot testing the instrument, the teacher-researcher added a qualifying clause asking the students to specifically explain any distractions they had. Students in the section not utilizing ALEKS instruction also completed the same daily questionnaire on the same day. However, instead of working with the ITS software, the students in the control group worked on concept practice problems created by the teacher. The teacher-researcher consequently analyzed and compared this data between the two groups and with the field notes in order to ensure the reliability of the research findings.

Observations. After receiving the data from the pre-research student attitude surveys and self-efficacy surveys, students began working on ALEKS software. One hundred percent of participants had their own school-issued Chromebooks that they are also allowed to take home. The initial step in working with this software involved students taking a knowledge check that measures what percent of the current course content the student possesses. This knowledge check took place on the second day of the content collection window for the experimental geometry group, after which all students had their learning path mapped out by ALEKS. The students then chose which topic they wished to work on from a list of topics that the software dictated that they were ready to learn. The students of one of the geometry classes worked on their learning path for a total of six one-hour sessions over the span of the three-week window while the other geometry class learned solely on teacher-led, content rich lessons aligned with SC state standards. At the midway point of the data collection timeframe, a posttest of the first instructional unit was be administered to both groups. The same protocol of pretest, instruction and posttest was followed for the implementation of the second geometry unit in the subsequent three weeks.

The teacher-researcher employed observations during the ALEKS lab time that were recorded in a field notes journal using the action research field notes form (Appendix D). Observations involved the systematic recording of what you see and hear in a particular setting (Mertler, 2007). On the same days that students of one group were working with the software system, the other group utilized traditional mathematics teacher-led instructional activities. The teacher-researcher recorded the observations in the field notes journal with both groups of students regarding the lesson observed. The qualitative data collected on these observations was analyzed inductively for pattern recognition and other insights that quantitative data cannot supply.

The goal of this field notes journal was to note the level of engagement of students, pertinent notes about daily lessons, and to reflect on changes that need to occur prior to the next lab session. An action research field notes form (Appendix D) was completed during (and after) each lab session; concurrently, an action research field notes form (Appendix D) was completed by the teacher-researcher for the students not working on the software. The teacher-researcher compared the qualitative data of the observations to see if there is a difference in the level of engagement between the two groups. The field journal notes was also compared to the answers from the student engagement questionnaires while the teacher-researcher looked for any emergent patterns between the two instruments.

The action research field notes form contained one 5-point Likert-scale question and four open-ended reflective questions regarding the student engagement of that particular day. A sample question is “How well did students practice the mathematics skills they were intended to practice?” (Appendix D). The teacher-researcher utilized the field notes journal during and after observations, and the data from the journal was used to enhance the interpretation of the data collected.

Student focus group interviews. Student interviews structured in focus group format was utilized as another data point in order to verify and triangulate the data. The student interview was comprised of four questions (see Appendix E) that are aimed at narrating the student's viewpoint on how using ITS systems has impacted their learning and levels of motivation. The goal of the focus group interview was to enable participants to discuss and expand on their own reflection of their learning. "Focus groups are especially useful when time is limited and because people are more comfortable talking in a small group, as opposed to individually" (Mertler, 2014, p. 133). The focus group was comprised of a purposeful selection of seven students of diverse backgrounds relating to race, ethnicity, and academic achievement. A semi-structured interview served as the best method of gathering qualitative data from students in this case because this scenario allowed the researcher to ask several foundational questions while exercising the option of following up a given response with an alternative question that may or may not be used by the researcher (Mertler, 2014).

Data Collection Methods

The data collection period lasted six consecutive weeks and included both quantitative and qualitative data collected during that time period. The timetable and procedures for the duration of the data collection period are summarized in Table 3.2. The teacher-researcher used her two geometry classes that already intact as her research population. The 45 participants were divided into two previously formed groups, the experimental group (N=23) and the control group (N=22). On the first day of data collection, all participants in both groups completed a Geometry concept-based pretest, a Mathematics Self-Efficacy Questionnaire (Appendix A), and a Student Attitude Survey (Appendix B). The teacher-researcher used this data at the end of the collection period in order to analyze and compare the information collected from both groups. On the second day of research the students in the experimental group completed the baseline knowledge check that ALEKS requires prior to the software delineating an individualized learning path for each student. The control group completed a written geometry course pretest, since they did not have access to the software.

During the next three weeks, the experimental group used the ALEKS software for two hours per week (spread over two separate days) during class time, while the control group was taught using standards-based whole group instruction. At the conclusion of each day that the intervention was used, both the experimental and the control group completed a student engagement daily questionnaire (Appendix C). In addition, the teacher-researcher completed the action research field notes form (Appendix D). The first instructional unit covered objectives on lines and angles that were divided into 40 small topics for students to master. Both groups completed the same posttest at the conclusion of the three-week period. The students' scores of both groups was analyzed using descriptive statistics (mean, median, and variance).

During the first day of the fourth week, both groups completed a pretest of the second geometry unit. The second unit covered objectives divided to 40 topics on concepts regarding parallel and perpendicular lines in geometry. At the conclusion of the sixth week, both groups completed another posttest. On the last day of data collection at the end of the six week period, participants in the intervention group also completed a mathematics self-efficacy questionnaire (Appendix A) and student attitude survey (Appendix B) in order to gather the post-research data points necessary for the analysis that follows. In addition, the teacher-researcher conducted a focus group interview, where she used the focus group interview questions instrument (Appendix E) to collect data from seven students chosen from the experimental group. The teacher-researcher was cautious to use a group that's diverse academically, racially, socioeconomically and culturally in order to gain quality, valid answers to the questions being asked.

Table 3.2
Procedural Time Table of Data Collection

Activities	**Week 1** Aug.	**Week 2** Sept.	**Week 3** Sept.	**Week 4** Sept.	**Week 5** Sept.	**Week 6** Oct.
Cumulative pretest assessments	X (day 1)			X (day 1)		
Student attitude survey (experimental group)	X (day 1)					X
Student-efficacy survey (experimental group)	X (day 1)					X
Initial knowledge check	X (day 2)					
Student engagement survey	X X	X X	X X	X X	X X	X X
Activities	**Week 1** Aug.	**Week 2** Sept.	**Week 3** Sept.	**Week 4** Sept.	**Week 5** Sept.	**Week 6** Oct.
Semi-structured observations	X X	X X	X X	X X	X X	X X
Cumulative posttest assessments			X (day 5)			X (day 5)
Focus group interview (experimental group)						X (exp. only)

Data Analysis

The current study is intended to analyze the impact of ITS on student achievement, motivation as it pertains to self-efficacy, engagement and student attitudes towards mathematics. The independent variable in this study was method of instruction and the four dependent variables were mathematics achievement, self-efficacy, student attitudes, and student engagement. The unit of statistical analysis was the student, but the only data that was considered for analysis in this study was the data of the students who have parental permission to participate. Determining the methods of analyzing data from a mixed-methods study means ensuring the diligence in analyzing the qualitative and the quantitative data concurrently. Dana & Yendol-Hoppey (2014) assert that the focus of summative data analysis is “to analyze and summarize what you’ve learned about yourself, your students, and your teaching as a whole” (p. 165). Although the teacher-researcher had insights about the process as the research developed and unfolded, she was cautious to wait until all data has been collected in order to analyze and reflect on the implications that may be surfacing.

The teacher-researcher used descriptive statistics in order to numerically summarize the scores of students and inferential statistics in order to determine if there is a significant difference between the two groups (Mertler, 2014). Through calculation of the mean and median values for the weekly curriculum assessments, the teacher-researcher can discuss the performance of the groups and how they compared with each other. Using a repeated measures *t* test, the teacher-researcher analyzed the results of the pretest and posttest of each of the two instructional units in both groups. A repeated-measures *t* test is often the preferred statistical method when measurements are taken from the same group of individuals before and after some intervention (Samuels, Witmer, & Schaffner, 2014). An independent-measures *t* test was used to compare the means of the two cumulative unit assessments between the two groups. If an independent-measures *t* test shows that difference of between the two means is statistically significant, it is very unlikely that the difference could be attributed to chance (Mertler, 2014).

To explore differences in student attitudes towards mathematics, this study analyzed results from the student SAS attitude survey and answers from the student interviews. The SAS survey measured positivity towards learning mathematics and school, collaboration with peers and teacher, as well as use of technology (Brookstein, Hegedus, Dalton, Moniz & Tapper, 2011). The initial attitudes and changes in attitudes were analyzed using descriptive statistics and a table displayed appropriate measures of central tendency. A *t* test was not used here as only the experimental group completed the attitude surveys. Furthermore, one of the purposes of student interviews was to elicit student responses on two of the above four factors, positivity towards learning mathematics and use of technology. After the focus group interviews were completed, the teacher-researcher looked for patterns that emerged on how use of ALEKS has impacted mathematics achievement and attitude towards mathematics.

In order to analyze the qualitative data, the teacher-researcher employed inductive analysis so that she can reduce the volume of information collected and organize the data into important patterns and themes. After perusing field notes and interview transcripts, it is imperative to begin noticing patterns and themes that develop into categories of narrative information. The above process is referred to as coding scheme and this process aids not only in the surfacing of the main features/characteristics of the data but also aids in the highlighting of the data that may contradict or conflict with the patterns that have already emerged (Mertler, 2014). An important consideration in analyzing qualitative data is to let the organizing units or categories emerge from the data rather than force an external set of units (Dana & Yendol-Hoppey, 2014).

Rigor and Trustworthiness

In a mixed methods study, quantitative and qualitative results were informally compared in order to examine if they have yielded similar results (Mertler, 2014). To address concerns of validity of a mixed-methods research design, all activities need to be meticulously and candidly documented. The-teacher researcher documented all journal entries during the ALEKS class days and immediately after students left the classroom. The teacher-researcher also completed a journal entry for the traditionally taught Geometry section. The semi-structured interview was done in small focus group, recorded, and then transcribed for future reference and analysis.

All of the cumulative unit pretests and posttests provide content validity as they were created after collaboration of mathematics teachers within Professional Learning Community groups and aligned to South Carolina state standards. The SAS instrument (Brookstein, Hegedus, Dalton, Moniz & Tapper, 2011) and MSEQ instrument (Kay, 2009) are valid and reliable data collection instruments as they have been scientifically proven in their respective studies. Convergence between sets of data leads to greater credibility, and triangulation ensures trustworthiness of qualitative data (Mertler, 2014).

In order to address internal validity, the teacher-researcher ensured that the groups are comparable before the study. Both groups consisted of 11th grade students who expressed interest in attending college. Ensuring that the two groups are comparable is one of the ways to address internal validity in a multiple group design (Dana & Yendol-Hoppey, 2014). This aided in preventing selection bias, as well as ensuring that any group differences that arose can be attributed to the treatment and not to any other pre-existing differences between the groups.

There are social threats present to internal validity of a multiple group research design. This is partially addressed by the two geometry groups being distinct and separate from each other, and by the fact that the treatment is only available to individual students in the experimental group only. One possible social threat to this study is compensatory rivalry. Compensatory rivalry occurs when differences between groups are increased due to increased efforts on the part of the control group to keep pace with the experimental group (Martella, Nelson & Marchand-Martella, 1999). Since teenagers tend to be very competitive in nature, the group not receiving the ALEKS instruction may want to work harder in preparing for the assessments just to beat the scores of the other group. It's also possible that the control group may even resent the experimental group for receiving the treatment, which may cause them to put forth a lot less effort. This is called resentful demoralization, which may actually taint the effectiveness of the treatment (Martella et al., 1999).

The issue of possible researcher bias presented the biggest challenge to the credibility of this research. The teacher-researcher maintained a high standard of ethics during this research process so that the final conclusions were derived from accurate reflection and analysis of the participants' experiences. The teacher-researcher exercised caution in ensuring that both groups are given equal attention and assistance during the days when the experimental group is working with ALEKS software. In efforts to remain unbiased, the teacher-researcher interpreted the data that was collected and made decisions solely on the results of the data, not her personal beliefs or aspirations regarding the subject being researched.

The teacher-researcher also maintained a high standard of ethics regarding the protection of the privacy and anonymity of the students. All students were assigned a pseudonym in order to protect their anonymity. A master list of the coding of student pseudonyms was kept under lock and key, only accessible to the teacher-researcher. This protected the privacy of students by preventing a person outside of the study to identify individual participants and their respective data (Mertler, 2017). The individual student data stored in ALEKS was only available to the student through a username and password access system, available to the student and the teacher-researcher only.

Summary

The research methodology in this chapter was intended to peel back the layers of the effect of ITS systems on mathematics achievement, motivation as defined by student self-efficacy, student attitudes, and engagement towards mathematics. The research problem should determine the type of research design that is chosen for a particular inquiry. A mixed method design was the best method for this action research as it calls for cautious perusing of the blending both qualitative and quantitative data. The teacher-researcher analyzed the quantitative data and began recognizing the patterns in the qualitative data while synthesizing the results in order to move forward in the research process. Action research helps transform school faculties into a community of learners thus building reflective practitioners while all along making progress on school-wide priorities (Sagor, 2000). A careful and thorough examination of the impact of ITS systems on Geometry students revealed pockets of insights that can help improve mathematics instruction and student achievement of students at Achieve High School.

The chapters in the remainder of this study explore the results of ALEKS when used during the instructional day on 11th grade geometry students. Chapter 4 of this study will reveal the results of the quantitative and qualitative data that is collected. Chapter 5 will discuss the findings, examine implications on current practice, and formulate an action plan for future studies.

CHAPTER 4

ANALYSIS

The purpose of chapter four of the current action research study is to convey the outcomes and analysis of the research. The data analysis includes quantitative and qualitative data collected in order to answer the following research questions:

1. What are the effects of ALEKS on 11th grade geometry students' skills of applying geometry theorems in mathematical contexts?
2. What are the effects of ALEKS on self-efficacy of 11th grade geometry students?
3. What are the effects of ALEKS on student attitudes of 11th grade geometry students?
4. What are the effects of ALEKS on student engagement of 11th grade geometry students?

The teacher-researcher employed deductive and inductive analyses in order to determine the effects of ALEKS, an Intelligent Tutoring Software system, on the achievement, self-efficacy, attitudes, and engagement of 11th grade geometry students.

Foundational constructs that ground this study include cognitivism, behaviorism, mastery learning theory, and self-efficacy theory. Cognitive theories acknowledge the importance of the activities occurring inside the human mind, and describe how information is received by the learner, organized, stored, and then retrieved by the mind (Ertmer & Newby, 2013). Behaviorist theory of reinforcement holds that learning through the interaction with the environment, and it is our responses to the environmental stimuli shapes our actions (Skinner, 1968). Mastery learning theory encompasses is the utilization of small units of instruction and repetitive testing over the units enhances the learning experience as students need to exemplify mastery before moving on to new material (Bloom, 1968). Bandura (1977) defines self-efficacy as the beliefs that a person hold about their own abilities to perform a task. One of the ways to build self-efficacy is through engaging in mastery experiences that result from dedicated efforts towards goal achievement (Bandura, 1977). It is the purposeful selection of these theories that ground the processes shaping the learning that occurs through the utilization of ITS systems.

Summary of the Research Design

The current research study took place in Achieve High School, a rural high school of 1,374 students in the small rural town of Dreamtown, South Carolina. The participants were 45 11th grade geometry students placed in two different classes. The intervention in this study is ALEKS, an intelligent tutoring software system that is web-based and utilizes artificial intelligence in order to teach and assess pedagogical content. This study employed a pretest-posttest multiple group design in order to accurately measure and assess the effects ALEKS on mathematics achievement, self-efficacy, attitudes, and engagement. One class utilized ALEKS twice a week while the other class used a standards-based, traditional instructional approach. This action study implemented a convergent mixed methods design, where qualitative and quantitative data was gathered at the same time but analyzed separately in order to establish a better understanding of the statistical findings and the emerging themes that surfaced in the study.

Description of data collection. The data collection instruments included pretests and posttests of two instructional units, pre-research and post-research student attitude surveys, pre-research and post-research student self-efficacy surveys, daily student engagement questionnaires, researcher field notes and focus group interviews. The researcher prepared for data collection in early August, prior to the first day of class. The data was collected over the course of six weeks. The initial interaction with students was to describe the study and to gain parental consent and student assent for participation (See Appendix A). The research sample consisted of a total of forty-five students divided between two groups (N=45) agreed to participate in the study by returning to the teacher-researcher both parental consent and student assent forms. The intervention group consisted of twenty-nine students, but only twenty three students had permission to participate in the study (N=23). The control group had twenty-eight students but only twenty two students agreed to participate (N=22). Prior to the beginning of any instruction, students in the intervention group were given a student attitude survey which measured student attitudes towards mathematics, school, and technology. In addition, students also completed a self-efficacy survey, which was aimed at measuring student self-efficacy towards their mathematics abilities. Both of these questionnaires served as pre-survey data prior to the intervention.

Students in both groups were given a pretest assessing their content knowledge prior to the first unit of study of geometry. For the next three weeks, the intervention group implemented ALEKS software in addition to whole-group instruction. On the days that ALEKS software was implemented, the students completed engagement questionnaires, and the teacher-researcher kept field notes in both the intervention and the control group classes. The purpose of collecting qualitative data was to solicit the student reactions in efforts to provide a richer, more in-depth understanding of the student experiences while learning with an intelligent tutoring system such as ALEKS. A posttest was administered and the process was repeated for a second instructional unit. At the end of the six weeks period, a focus group interview was conducted, where twelve students from the intervention group with diverse backgrounds, ethnicity and academic abilities came together to discuss their experiences with learning with the ALEKS software. The interview was audio recorded for qualitative data, then transcribed and coded for emerging themes that would enhance the findings of this research. At the conclusion of the study, the teacher-researcher used Excel software for accurate and efficient statistical analysis. All student names were replaced with pseudonyms and only the responses of students who agreed to participate in the study were included.

Quantitative Data Analysis

The quantitative data consisted of (1) a pre- and post- research Student Attitude Survey (SAS) that measured the students' attitudes and beliefs towards mathematics, (2) a pre- and post- research self-efficacy questionnaire, and (3) a pre- and posttest assessment of two geometry units that measured the students' ability to apply geometry theorems in mathematical contexts. A dependent t-test was conducted for the pre- and post- research SAS, the pre- and post- research self-efficacy questionnaire, and the two pre- and post-assessments of the two geometry units in order to measure whether there was a significant difference after the intervention.

Student achievement. For purposes of this study, mathematics achievement is measured based on the ability of students to apply geometry theorems in mathematical contexts. Students in both groups were administered a pretest and a posttest on two instructional units and the results were analyzed using inferential statistics to determine whether there is a significant difference between the means of the two groups. The unit assessment questions were selected by the teacher-researcher in conjunction two other geometry teachers through the weekly Professional Learning Community (PLC) meetings and the questions were based on content area standards for geometry. Each unit assessment has 32 open-ended, content specific questions involving applying geometry theorems in mathematical contexts. Unit 1 included questions about foundational segment and angle theorem applications in geometry and Unit 2 assessment included questions about line and plane theorem applications. When entering student results in Excel software for analysis, all student names were removed and replaced by pseudonyms in order to protect the anonymity of the participants.

Intervention pre- and posttest student results. The teacher-researcher found the statistical measures of central tendency for the pre- and the posttests for both instructional units and for both the intervention and the control groups as shown in Table 4.1 below for Unit 1 and Table 4.2 below for Unit 2. Student results show that although both the intervention and the control group show gains between the pre-test and the post-test in both units, the intervention group shows a slightly higher growth between the pre-test and the post-test assessments. Between the Unit 1 pre- and posttest, the intervention group as a whole gained 5.9 points more than the control group, and in Unit 2 pre- and posttest the intervention group gained 4.9 points more than the control group.

Table 4.1

Pre- and Posttest Means of Intervention and Control Groups of Unit 1

	N	Pre-test Mean	Pre-test Std. Dev.	Std. Error Mean	Post-test Mean	Post-test Std. Dev.	Std. Error Mean	Difference in Means
Intervention Group	23	18.6	6.59	1.37	75.7	17.22	3.59	57.1
Control Group	22	20.8	7.64	1.63	72	18.48	3.94	51.2

Table 4.2

Pre- and Posttest Means of Intervention and Control Groups of Unit 2

	N	Pre-test Mean	Pre-test Std. Dev.	Std. Error Mean	Posttest Mean	Post-test Std. Dev.	Std. Error Mean	Difference in Means
Intervention Group	23	14	6	1.25	72.6	19.36	4.04	58.6
Control Group	22	15.2	6.91	1.47	68.9	17.87	3.81	53.7

After recording the student scores in Excel, the teacher-researcher conducted a dependent *t*-test analysis in order to determine if any statistically significant changes occurred due to the method of intervention or due to random chance. Results of the dependent t-test analysis can be found below in Table 4.3 for both instructional units, for both groups. Results showed that both groups showed statistically significant growth, regardless of the method of intervention ($p<0.05$). The results suggest that this growth can be attributed to the method of instruction and that it is not due to chance. Therefore, both methods of instruction led to a statistically significant increase in student applications of geometry theorems in mathematical concepts.

Table 4.3

Dependent t-test for Pre- and Posttests of Two Instructional Units for Intervention and Control Groups

	T	Df	Sig. (2-tailed)
Pair 1 Unit 1 Pre- to Unit 1 Posttest Intervention Group	21.66	22	0.0000
Pair 2 Unit 1 Pre- to Unit 1 Posttest Control Group	18.52	21	0.0000
Pair 3 Unit 2 Pre- to Unit 1 Posttest Intervention Group	17.54	22	0.0000
Pair 4 Unit 2 Pre- to Unit 1 Posttest Control Group	18.26	21	0.0000

Lastly, the teacher-researcher conducted an independent samples *t*-test for both instructional units in order to compare the mean scores of the assessments between the two groups of students. An independent *t*-test is aimed to determine whether there is a statistically significant difference between the mean scores of two unrelated groups (Mertler, 2017). As seen in Table 4.4, the intervention group scored only slightly higher than the control group on both instructional unit assessments but the difference was not large enough to be statistically significant. On Unit 1 assessment, the mean score for the intervention group (M = 76.65) was not significantly higher than the mean for the control group (*M* = 71.95), *t* = 0.88, *p* = .38. On Unit 2 assessment, the mean score for the intervention group (*M* = 72.57) was not significantly higher than the mean for the control group (*M* = 68.91), *t* = 0.66, *p* = .51.

Table 4.4
Independent t-test for Pre- and Posttests of Two Instructional Units for Intervention and Control Groups

Instructional Unit		Intervention (n=23)	Control (n=22)	*t*-value
Unit 1	M	76.65	71.95	0.88
	SD	(17.22)	(18.48)	
	DF	22	21	
Unit 2	M	72.57	68.91	0.66
	SD	(19.36)	(17.87)	
	DF	22	21	

The results from the independent *t* test support that the means of the posttests of the two instructional units for geometry were not significantly different. Although minimal differences do exist between the two groups, results of the independent *t* test suggest that these differences might not be due to the impact of the intervention (ALEKS software).

Self-efficacy. In order to measure self-efficacy, the teacher-researcher utilized the mathematics self-efficacy questionnaire containing 18 5-point Likert type questions. This was developed by the teacher-researcher by modifying an original mathematics self-efficacy and anxiety questionnaire that was written, pilot tested and used in a study by measuring student self-efficacy and anxiety towards mathematics (May, 2009). The original mathematics self-efficacy and anxiety questionnaire was modified so that only 18 of the 29 questions that were pertinent to self-efficacy were measured. The student answers range from 1(strongly disagree) to 5(strongly agree). The self-efficacy questionnaire was purposefully given only to the group utilizing ALEKS as the teacher-researcher was only interested in measuring the effects of ALEKS on the self-efficacy of specifically the intervention group. Since the control group was not utilizing the intervention, the teacher-researcher did not find it necessary to analyze shifts in self-efficacy of those students. The teacher-researcher was only interested in seeing shifts in self-efficacy due to implementation of ALEKS software. Below is a presentation of the pre- and post-research of self-efficacy questionnaire student responses, and the increases and decreases for each question comparing the pre-research to post-research results of the intervention group.

Intervention pre- and post- research self-efficacy survey results. The intervention group consisting of 23 students exhibited minimal increases in the beliefs of student self-efficacy or the belief in themselves that they can achieve in mathematics. In Table 4.5 that follows is a presentation of the student responses for each individual question, both from the pre-intervention and the post-intervention questionnaire administration. For purpose of this analysis, the teacher-researcher grouped student responses in three categories: strongly disagree/disagree, no opinion, and agree/strongly agree. Their responses are represented as a percent, and a discussion of these results follows below.

Table 4.5

Pre-and Post-Research Questionnaires on Self-Efficacy of Intervention Group

n=23		Strongly Disagree/Disagree	No opinion	Agree/Strongly Agree
I have been able to understand	Pre	17.4%	56.5%	26.1%
mathematics.	Post	0%	21.7%	78.3%

(table continues)

Table 4.5

Pre-and Post-Research Questionnaires on Self-Efficacy of Intervention Group

n=23		Strongly Disagree/Disagree	No opinion	Agree/Strongly Agree
I have done well in my mathematics course.	Pre	21.7%	34.8%	43.5%
	Post	0%	39.1%	60.9%
I am the type of person who is able to learn mathematics well.	Pre	39.1%	34.8%	26.1%
	Post	13%	21.7%	65.2%
I believe I can do the mathematics in this geometry course.	Pre	8.7%	26.1%	65.2%
	Post	4.3%	4.3%	91.3%
I have enjoyed mathematics.	Pre	47.8%	39.1%	13%
	Post	13%	43.5%	43.5%
I believe I am the kind of person who is good at mathematics.	Pre	39.1%	39.1%	21.7%
	Post	17.4%	26.1%	56.5%
Mathematics instructors have been willing to help me learn the materials.	Pre	8.7%	43.5%	47.8%
	Post	0%	17.4%	82.6%
I have worked hard in my mathematics classes.	pre	13%	34.8%	52.2%
	Post	4.3%	4.3%	91.3%

(table continues)

Table 4.5

Pre-and Post-Research Questionnaires on Self-Efficacy of Intervention Group

n=23		Strongly Disagree/Disagree	No opinion	Agree/Strongly Agree
I believe I can understand the content in a mathematics course.	Pre	13%	39.1%	47.8%
	Post	4.3%	8.7%	87%
I believe I can learn well in a mathematics course.	Pre	17.4%	17.4%	65.2%
	Post	0%	17.4%	82.6%
I believe I can complete all of the assignments in this geometry course.	Pre	21.7%	21.7%	56.5%
	Post	8.7%	17.4%	73.9%
I believe I can do well on a mathematics test.	Pre	4.3%	52.2%	43.5%
	Post	0%	17.4%	82.6%
I believe I can think like a mathematician.	Pre	39.1%	30.4%	30.4%
	Post	30.4%	21.7%	47.8%
I believe I can get an "A" when I am in a mathematics course.	Pre	26.1%	26.1%	11%
	Post	17.4%	17.4%	65.2%
I have set goals in my mathematics classes.	Pre	13%	26.1%	60.9%
	Post	0%	34.8%	65.2%
I regularly do assigned homework.	Pre	17.4%	13%	69.6%
	Post	4.3%	8.7%	87%

(table continues)

Table 4.5

Pre-and Post-Research Questionnaires on Self-Efficacy of Intervention Group

n=23		Strongly Disagree/Disagree	No opinion	Agree/Strongly Agree
I have asked questions in my mathematics classes.	Pre	21.7%	30.4%	47.8%
	Post	17.4%	30.4%	52.2%
I have sought help from mathematics instructors outside of class.	Pre	52.2%	13%	34.8%
	Post	47.8%	26.1%	26.1%

It is important to note that 17 out of the 18 questions showed an increase in positive beliefs regarding student self-efficacy between the pre-research and the post-research surveys. The top six questions with the greatest percentage gains in the category 'Agree/Strongly agree' between pre-research and post-research in descending order are "I believe I can get an 'A' when I am in a mathematics course," "I have been able to understand mathematics," "I believe I can understand the content in a mathematics course," "I have worked hard in my mathematics classes," "I am the type of person who is able to learn mathematics well," and "I believe I can do well on a mathematics test." This showed an increase in the perceived student ability to understand, and learn mathematics, as well as an increase in perceived student ability perform the mathematics demanded of them in order to excel in geometry. Only one question showed a decrease in positive beliefs between the pre-research and post-research survey results, which was the question "I have sought help from my mathematics instructors outside of class". This points to the students perceiving themselves as needing less help from a teacher and growing to be more independent.

Student attitudes. The pre- and post-research student attitude survey was modified by the teacher-researcher from the original survey developed by Brookstein, Hegedus, Dalton, Moniz & Tapper (2011) in order to measure student attitudes and beliefs towards mathematics. The teacher-researcher chose 19 out of the original 27 questions that were paramount to this specific research. The participants of the study were asked to report the extent to which they agreed or disagreed to a statement on a scale of 0 ("Strongly Disagree") to 4 ("Strongly Agree") to the 19 questions, and they took the identical SAS survey upon the conclusion of the research study at the end of the six weeks. Since the teacher-researcher was sonly interested in seeing shifts in student attitudes when utilizing ALEKS software, she did not find it necessary or useful to collect shifts in student attitudes from the participants in the control group. The student attitudes survey was only given to students in the intervention group utilizing ALEKS software as part of their geometry instruction.

For purpose of this analysis, the teacher-researcher grouped student responses in three categories: strongly disagree/disagree, no opinion, and agree/strongly agree. Their responses are represented as a percent, and a discussion of these results follows below. The shifts in student attitudes from pre-intervention to post-interventions are discussed below and in Tables 4.6 and Table 4.7 that follow.

Intervention pre- and post- research student attitude results. The intervention group consisted of 23 students who showed both positive and negative shifts in attitudes after six weeks of implementing the intervention. Fifteen questions showed positive shifts in student attitudes from the pre-research to the post-research questionnaire, and the individual student responses are shown below in Table 4.6.

Table 4.6

Pre- and Post-Research Student Responses Indicating Positive Shifts in Attitudes

n=23		Strongly disagree/Disagree	No opinion	Agree/Strongly Agree
I enjoy using a computer when learning mathematics.	Pre	26.1%	4.3%	69.6%
	Post	8.7%	13%	78.3%
Technology can make mathematics easier to understand.	Pre	13%	21.7%	65.2%
	Post	8.7%	17.4%	73.9%
I enjoy hearing the thoughts and ideas of my peers in math class.	Pre	4.3%	39.1%	56.5%
	Post	13%	13%	73.9%
I feel confident in my abilities to solve math problems.	Pre	8.7%	39.1%	52.2%
	Post	4.3%	26.1%	69.6%
I receive good grades on math tests and quizzes.	Pre	8.7%	34.8%	56.5%
	Post	4.3%	21.7%	73.9%
I think mathematics is important in life.	Pre	4.3%	13%	82.6%
	Post	0%	13%	87%
When using technology for learning math, I feel like I am in my own private world.	pre	43.5%	8.7%	47.8%
	Post	8.7%	8.7%	82.6%
Mathematics interests me.	Pre	34.8%	39.1%	26.1%
	Post	17.4%	52.2%	52.2%

(table continues)

Table 4.6

Pre- and Post-Research Student Responses Indicating Positive Shifts in Attitudes

n=23		Strongly Disagree/Disagree	No opinion	Agree/Strongly Agree
In previous high school math courses, my math teachers listened carefully to what I had to say.	Pre	0%	21.7%	78.3%
	post	4.3%	8.7%	87%
I learn more about mathematics working on my own.	Pre	34.8%	30.4%	34.8%
	Post	17.4%	26.1%	56.5%
I like math.	Pre	30.4%	26.1%	43.5%
	Post	17.4%%	26.1%	56.5%
When I see a math problem, I am nervous.	Pre	17.4%	39.1%	43.5%
	Post	47.8%	21.7%	30.4%
I like to go to the board or share answers with peers in math class.	Pre	73.9%	17.4%	8.7%
	Post	52.2%	13%	34.8%
I am not comfortable with using technology in class.	pre	65.2%	21.7%	13%
	post	73.9%	17.4%	8.7%
I sometimes feel nervous talking out-loud in front of my peers.	pre	21.7%	17.4%	60.9%
	post	34.8%	17.4%	47.8%

The positive increases in student attitudes while implementing ALEKS software showed that students in the intervention group are changing their attitudes and beliefs towards learning mathematics. The students in the intervention group perceive a greater importance of mathematics in life, share a greater interest in the subject of mathematics, and perceive that their confidence in solving mathematics problems has increased. They have stronger perceptions about technology making mathematics easier to understand and their enjoyment of using a computer when learning mathematics has increased. Students are perceiving that their mathematics grades are better, while they are liking hearing the thoughts and ideas of their peers more. They are less nervous to speak up in front of their peers and less nervous when seeing a mathematics problem. They are more eager to participate in discussions that involve math, and they are more comfortable when using technology in mathematics class.

Four questions show a negative shift in attitudes and beliefs of students towards learning mathematics. In Table 4.7 that follows, the answers for each question are explain in terms of students who strongly disagree/disagree, students who have no opinion, and students who agree/strongly agree with each statement.

Table 4.7

Pre- and Post-Research Student Responses Indicating Negative Shifts in Attitudes

n=23		Strongly disagree/Disagree	No opinion	Agree/Strongly Agree
I get anxious in school.	pre	34.8%	30.4%	34.8%
	post	21.7%	26.1%	52.2%
I do not like school.	pre	17.4%	30.4%	52.2%
	post	4.3%	34.8%	65.2%

(table continues)

Table 4.7

Pre-and Post-Research student Responses Indicating Negative Shifts in Attitudes

n=23		Strongly Disagree/Disagree	No opinion	Agree/Strongly Agree
In the past I have not enjoyed math class.	pre	17.4%	34.8%	47.8%
	Post	26.1%	8.7%	65.2%
I am not eager to participate in discussions that involve math.	pre	26.1%	34.8%	39.1%
	post	26.1%	30.4%	43.5%

The persistence and increase of negative attitudes towards learning mathematics reveal that students continue to experience difficulty when mastering mathematics content. Students voice that they feel slightly more anxious in school and state that they are not eager to participate in discussions. In addition, students perceive that they are disliking school and their mathematics class more.

The increases in positive attitudes and beliefs of students towards learning mathematics while utilizing ALEKS software points to having a greater interest and confidence towards mathematics. The participants are showing improved attitudes towards utilizing technology as part of mathematics instruction as they voice more comfort and enjoyment in using technology while learning mathematics. Survey results also show a student increase in the value they place on technology helping making mathematics easier. The results of this survey also indicate that while students perceive their math grades have improved, they still possess a negative attitude towards school and less enjoyment towards the subject of mathematics.

Student engagement. At the conclusion of each day that the intervention is used, both the experimental and the control group completed a student engagement daily questionnaire (Appendix C). This questionnaire consisted of three questions asking the students in both the experimental and the control group to reflect on their level of engagement and to justify their answers. In the first question, the students had to rate themselves on how well they are being on task on a level of 1 to 5, with 5 being the best, and to justify their answers. In the second question, the students had to rate themselves on how well they appropriately practiced the skills they were working on a scale of 1 to 5, with 5 being the best, and to justify their answers. In the third question, students had to write about what the most important concept they worked on during the lesson.

Quantitative analysis of student engagement questionnaires. The intervention group consisted of 23 students who completed the Student Engagement Questionnaire on the days that they utilized ALEKS software as part of their instruction. The control group consisted of 22 students who completed the same engagement questionnaire while mastering Geometry concepts, but this group did not utilize the ALEKS software program. All students had to choose a number between *1* and *5*, with *5* being the best. Results are summarized below and also on Table 4.8 for the first question, how well students rated themselves on being on task, and Table 4.11 for the second question, how well they feel that they practiced the skills they were supposed to be working on.

- On the first question asking the students in the intervention group to rate how well they rated themselves on being on task, three students (13%) rated themselves as '1' or '2', seven students (30%) rated themselves as a '3', and 13 students (57%) rated themselves as '4' or '5'.

- On the first question asking the students in the control group to rate how well they rated themselves on being on task, four students (18%) rated themselves as '1' or '2', 11 students (50%) rated themselves as a '3', and seven students (32%) rated themselves as '4' or '5'.
- On the second question asking the students in the intervention group how well they feel that they appropriately practiced the skills they were supposed to be working on, three students (13%) rated themselves as '1' or '2', six students (26%) rated themselves as a '3', and 14 students (61%) rated themselves as '4' or '5'.
- On the second question asking the students in the control group how well they feel that they appropriately practiced the skills they were supposed to be working on, three students (14%) rated themselves as '1' or '2', eight students (36%) rated themselves as a '3', and 11 students (50%) rated themselves as '4' or '5'.

Table 4.8

Student Engagement Questionnaire Results

	Percentage of students responses of 1 or 2	Percentage of student responses of 3	Percentage of student responses of 4 or 5
Student responses on how they rated themselves on being on task.			
Intervention Group	13%	30%	57%
Control Group	18%	50%	32%
Student responses on how well they feel they practiced the appropriate skills.			
Intervention Group	13%	26%	61%
Control Group	14%	36%	50%

So in both questions, students in the intervention group indicated a higher level of engagement than in the control group. More students had neutral responses in the control group regarding the level of engagement than the intervention group. In the second question, 61% of the students in the intervention group saw themselves as practicing the appropriate skills and rated themselves as a 4 or a 5, whereas 50% of students in the control group rated themselves in the same manner. So both groups of students perceived themselves as being engaged and working towards mastery of new content.

Students in both groups gave short justifications to their answers, which will be discussed in the qualitative analysis section of this chapter. Although all students answered the student engagement questionnaires, it was observed by the teacher-researcher that they did it very quickly as evidenced by their short, one-word answers and insufficient justifications.

Qualitative Data Analysis

The qualitative data consisted of the data collected from a semi-structured interview, the field notes recorded by the teacher-researcher, and the student engagement questionnaires. Qualitative data is narrative in nature, and its analysis involves the inductive process of detecting patterns and organizing it into important themes (Mertler, 2017). The qualitative data in this semi-structured interview was collected through direct interaction with the student-participants and all notes were kept secure in a locked cabinet.

Semi-structured focus group interview. The interview lasted approximately 52 minutes and it involved a focus group consisting of seven students. These student-participants were carefully selected by the teacher-researcher based on the course grade and classroom observations in order to represent a cross section of mathematics ability levels and motivation. The student-participants were then asked some open-ended questions about their opinions, beliefs, perceptions and attitudes regarding their learning experiences with ALEKS. The interview was recorded and transcribed afterwards by the teacher-researcher, and was subsequently coded and analyzed in order to discern surfacing patterns and themes. All student-participants were assigned a pseudonym in order to protect their identities.

The three emerging themes from this analysis were promoting independence, developing fluency, and beliefs about technology. Promoting independence addressed the ability of the students to learn at their own pace while becoming advocates for their own learning. Developing fluency addressed the structure of the software system ALEKS and how this structure helped students master and retain mathematics. Beliefs about technology addressed the student reactions to incorporating technology while learning mathematics.

***Promoting independence*.** This theme addressed how incorporating ALEKS software influenced students as learners and as mathematicians. Many students discussed how learning geometry with the software has helped them become independent thinkers. Alysa best summarized that when she stated, "You can work with yourself on getting problems right and understanding it better. Plus, I think you get a better understanding if you get it for yourself other than asking someone else." Students made sense of the learning *for* themselves and *by* themselves, using their teacher only when they needed guidance or if they felt "stuck." Students voiced that learning with the software helped them with goal setting, as they could quantify how many topics they aimed to accomplish during that lesson. ALEKS organizes content into individual topics, and students set learning goals of how many topics they choose to master during the instructional time. Mylah stated, “You feel that you really accomplished something if you meet your five or seven or ten topics you wanted to do that day.” Oliver expanded on that concept by stating that “If you don’t accomplish what you wanted in class then you know you can access this at home. This makes us have more responsibility.” Student comments point to how the mastering of topics helps them feel that they have achieved their goal.

Additionally, promoting independence seems to be derived from the software enabling the student to individualize their learning. Sonia stated, “I like how I can go at my own pace, and when I don’t understand something I can skip it and I can go do something else.” Echoing what Sonia said, Mason stated “People don’t get it as fast as other people, what takes someone five or ten minutes can take someone else thirty minutes. That’s me, I need more time.” Many students stated how in the traditional classroom they felt rushed and could not take a mental break if they wanted to. These students expressed the difficulty they had by trying to keep up with the pace in a traditional learning environment and how being able to learn while setting their own pace helped lessen their frustrations as math students.

Four of the students discussed how learning with ALEKS helped them become advocates for their own learning. Since the learning interaction occurs between the student and the software program, the responsibility to ask for clarification or guidance from the teacher lies entirely on the student. Students discussed how they were not afraid to speak up and ask for help from the teacher. Ethan stated, “In my previous math classes, people didn’t speak up that much. They asked me for help, and I didn’t know how to do it either. Now everyone raises their hands when we are working on the computer." Alysa further supported Ethan's statement by saying, "In the classroom you are scared to say something in front of your classmates you are scared that they will think it will be stupid or dumb. But now no one knows what you get wrong except for the computer and your teacher." These students echoed how they found themselves speaking up more about what they did not understand and what concepts they needed the teacher's help on in order to develop further.

The software ALEKS helped students promote independent thinking and goal setting. Utilization of the software helped individualize the pace and content of learning. In addition, students utilizing ALEKS software took more initiative in asking questions and interacting with the teacher-researcher. They were more confident in speaking up about their academic needs and asking for clarification on mathematical problems.

Developing fluency. The theme of developing mathematical fluency addressed the structure of the software system ALEKS and how this structure helped students master and retain mathematics. Students discussed the introduction to new topics that the software program provides and how this serves as a preview to what is being taught in the classroom. Oliver stated, "It brings the topics to us before you do them. It preps us for what is coming up next." Sonia echoed Oliver's statement by exclaiming, "Yea, and when you teach us something new, some people say 'I saw that on ALEKS!' I like that!" Most students saw the ability to preview upcoming standards that were taught in the classroom as a privilege made possible by the utilization of the software.

All students elaborated on how important the practice generated by the software was and how much it helped them master the geometry topics. They discussed how the nature of the software problem lends itself to providing endless examples and how helpful that was for them when they struggled. Mason stated, “Because we have so many kids in here, you can’t give us example after example and work with us the entire day. But ALEKS can, it can explain things to us a million times.” Students also highlighted how this endless practice is tailored to their specific needs. Tara, stated:

> I like how ALEKS gives us multiple, endless problems, examples, and explanations on certain things that we have a hard time on. I understand with the teacher her time is limited, so she can give you one or two examples, and that’s all you can do. But ALEKS works on us individually and keeps giving us problems till it makes sure we know it.

Mylah agreed with Tara, and added “If you tell someone to study or practice math they don’t know what to do. But ALEKS knows what you need to do, it has topics you can practice”. Many students overwhelmingly stated awareness of how limiting it is to be in a classroom full of students taught by a single teacher. They voiced awareness that the teacher is limited in the amount of examples and explanations he/she can provide in the regular classroom setting whereas the software is able to give multiple practice problems and explanations.

Students expressed how learning with ALEKS impacted them in retaining old concepts while learning new ones. They discussed how easily they forget mathematics, and how they always need for their teachers to review everything before a test. Ethan claims:

> ALEKS makes you remember stuff by giving you one topic, then they give you another topic, and they switch it up making you think it’s different. But it’s the

> same thing you just did not too long ago. It's repeating so you can get it for another time, so if you have a test later you know it.

Ethan supported the concept that ALEKS helps with retaining geometry topics by discussing how students cannot move on if they have not mastered the topics. He elaborated on how students can utilize the explanations provided by the software in order to understand where they are making mistakes, but continue to practice after they make their mental or written notes. He stated: "I write down the explanations a lot, this helps me remember. Some people don't write anything down, they just read them." Alysa added, "While I am in ALEKS I can get multiple explanations and if I am having trouble with one thing I can move on to another". Many students echoed how the explanations provided by the software helped them remember concepts they had otherwise forgotten, and how the ability to write down what they perceived as important and necessary was helpful in order for them to keep progressing.

Students further debated on how the knowledge checks throughout the learning experience helped them with retaining topics. Most of the students found the periodic knowledge checks to be challenging as they required them to synthesize information that they have previously learned. Furthermore, although they found it frustrating when the software made them go back and study previous topics they had already mastered if they missed the correlating questions on the knowledge check, they still saw the value in having to repeat lessons that they forgot. Mylah, stated:

> The knowledge checks help keep you learning. You can't move on till you show them you know it. You are actually learning. And if you don't really know it you can do that topic again until you actually can do it right.

Tara, echoed Mylah by stating: "I like the knowledge check because I think I understand it but when I get the knowledge check it shows me what I really understand and what I need more practice on." Some students voiced a dislike for the knowledge checks based on the level of difficulty they encountered while taking them. Mason, claimed: "I don't like the knowledge check, they are like IQ tests, only harder". Students also disliked how they did not know if they were answering questions right or wrong while taking the test, but rather had to wait until the end to see if the knowledge check made them study a topic that they had previously already learned. Alysa, explained: "So you don't know right there if you missed a question until you go back and relearn the topic. Relearning helps remembering, but it's aggravating. It's like an IQ test on that." Although students found the process of relearning a topic as a burden, they all agreed that it helped them retain concepts that they found difficult or confusing.

Student responses point to the utilization of ALEKS serving as a vehicle to master and retain geometry topics. Although periodic knowledge check help with the retention of topics, relearning a geometry topic previously mastered was somewhat frustrating for students. The multiple practice problems and explanations generated by ALEKS allow for the mastering of the content and for students to continue practicing new concepts while internalizing the ones they just learned.

Beliefs about technology. Beliefs about technology addressed the student reactions to incorporating technology while learning mathematics. Students exhibited inconsistency in their feelings towards learning geometry while utilizing ALEKS software. Although all students viewed the practice component of the software as necessary and helpful, most students voiced concerns about not knowing exactly where they made a mistake when they were solving a problem. Tara discussed how when she is working with a teacher, the teacher is always able to direct her learning by highlighting the errors in her mathematical reasoning, whereas a software system such as ALEKS simply tells you that a problem is wrong and cannot discuss faults in the thinking process. She stated:

> Sometimes our minds skips over steps, and everything is wrong we still have trouble finding where we messed up at. ALEKS gives us explanations over how to do the whole problem but not find where we messed up at, it just tells us it's wrong.

Some students discussed concerns about computer software replacing the teacher and they shared views about how learning while utilizing technology is equivalent to learning by themselves. Their discussion also implied that they connect direct instruction in a setting led by a teacher to active learning. Oliver, said: "My brain isn't active when I am in front of the computer. When the teacher is teaching, she is active, you are active, and your brain is active." Ethan discussed how he prefers learning with direct instruction over any form of computer assisted learning. He stated:

> I learn better if someone is in front of me, telling me this is how you set it up, this is how to write it, this is how to do it. I like that better than me trying to figure it out how to do it by myself on the computer.

Some students discussed the fatigue that is related by working on the computer for a prolonged period of time. They explained how technology has been infused in all of their classes, and how it gets tiring to be constantly sitting in front of a computer monitor. Alysa, stated: "I feel like we already look at screens too much; being in front a screen constantly is exhausting." Ethan disagreed with Alysa, by claiming: "Not me! I get tired to listening to people talk all the time!" Tara agreed with Ethan by saying: "I don't like learning in the classroom cause some people get more distracted easily." It was evident by the student conversations that they held opposing views about learning, especially learning mathematics, with technology.

While some students discussed the frustrations brought forth by technology lessons, others elaborated on how motivating it is to learn with ALEKS. Sonia explained how some days she does not feel like learning, but just being able to learn a few new topics is an achievable goal. She stated: "Somedays I don't want to do anything, I want to take a break. Once I get in ALEKS, I say I just want to get these [topics] done. Then time just flies." Students also discussed how being able to receive one-on-one help from the teacher while working on ALEKS was invaluable, mostly because they were able to ask private questions. They discussed how the amount of help that they receive from their teacher was completely up to them, and that some days they asked many clarification and guidance questions and some days none. Mason discussed his difficulties with asking questions in the traditional setting as he felt that everyone around him was smarter than he was. He stated: "I ask lots of question while I work on ALEKS. Nobody knows what I am asking and I like that." Ethan, who discussed how he is generally quieter than everyone else, stated "ALEKS is a self-mind thing. If you make up your mind, you can learn a whole bunch of stuff, [by asking] questions or not". Many students discussed how they found value in the individualized, private learning path carved by ALEKS software.

The student responses collectively point to the inconsistency that exists regarding utilizing technology while learning mathematics. The ability to set goals and work towards achieving them served as a source of motivation for students. In addition, this software provided a learning opportunity where students can ask private questions about the content they were learning, not fearing other students criticizing their mathematics ability. ALEKS software, unlike a classroom teacher, does not point out exactly where students make a mistake, which can be a source of student frustration. Students can also feel more fatigued while they are using technology, due to the constant need to focus on the screen in front of them during their educational day. Overall, student statements were incongruent with each other regarding the use of technology while learning mathematics.

Field note analysis. The teacher-researcher recorded observations of the lessons in a field notes journal for both groups on the days that the intervention group was using ALEKS software. The goal of keeping a field notes journal was to note the level of engagement of students, pertinent notes about daily lessons, and to reflect on changes that need to occur prior to the next lesson. The field notes were both descriptive and reflective in nature, whereas the teacher-researcher documented actions and behaviors of the students, along with recording personal thoughts and ideas regarding the lesson. The descriptive notes were written while watching, listening and interacting with the students. The teacher-researcher wrote down any reflective notes immediately after the lesson, in order to accurately capture her thoughts, ideas and concerns. The teacher-researcher then used coding in order to find any emerging themes. Two overwhelmingly strong themes that surfaced from the field notes were the nature of questioning and level of student engagement. The theme nature of student questions discussed the difference in quantity and the quality of questions asked between the intervention group, that was utilizing ALEKS software as part of their instruction, and the control group, which was taught using a more standards-based, traditional approach. The theme difference of student behaviors encompasses a discussion of the difference of student behaviors regarding classroom engagement that were observed during instruction in both classes.

Nature of student questions. The analysis of the field notes revealed that a great disparity existed between the quantity and the quality of questions asked by the students in the ALEKS classroom versus the traditional classroom. Field notes expressed that whereas in the ALEKS classroom students asked anywhere from 15-30 questions during the class, the students in the traditional classroom asked 2-10 questions on the same day. The students that were utilizing the software raised their hands and waited on the teacher-researcher to come to their desk and clarify or explain a concept. At any given point during the lesson, there were always a minimum of two students having their hands raised in the ALEKS group, whereas in the traditional group there were long periods of at least fifteen minutes where no student raised their hands wanting help from the teacher-researcher. The field notes state how the teacher-researcher was the one initiating conversations with students in the traditional classroom setting whereas in the intervention group, the students initiated 100% of the interactions with the teacher. On the field note of Session #2 of the ALEKS group the teacher-researcher wrote:

> Today I was overwhelmed. I answered questions the entire ninety minutes. I think I talked with all of my students, at least twice. They had a lot of questions, and some of them [the students] were really stuck. They seemed to be very encouraged when I asked them to call me back if they still cannot proceed after my clarification.

The notes revealed that students in the control group were not as actively involved in their learning, and seemed to be behaving in a more robotic, taciturn manner. Although the notes clearly stated that students appeared to be more silent in the control group, the students in the intervention group were more active and responsive about their learning needs.

The field notes also revealed that students in the intervention group asked a greater variety of questions, often possessing more depth and wonder. The questions in the control group mostly consisted of asking the teacher-researcher how to proceed with a problem, or most of the times students raised their hands to say that they are not able to solve a problem. In the intervention group, however, students asked a variety of questions, from asking about how the explanation provided by ALEKS calculated a certain number, stating that they could not proceed past a certain step, claiming that they never learned a concept (such as solving a multi-step equation) in a previous mathematics class, or asking for an alternate representation of a problem after reading through the instructional resources that ALEKS provided. The field notes reveal that students in the intervention group more active in their learning by utilizing the software and the help of the teacher-researcher while learning new concepts.

Analysis of the field notes showed that the questions differed in quantity and quality between the intervention group and the control group. Students who utilized ALEKS software as part of their instruction asked more than double of the questions in the control group. In addition, the questions these students asked had greater depth and topic variance when compared to the questions asked by students in the control group.

Lastly, students in the intervention group asked questions that allowed for filling in their previous learning gaps, and for strengthening their overall mathematics skills.

Difference of student behaviors. The field notes revealed that there existed many differences in the types of student behaviors observed between the intervention group utilizing ALEKS software and the control group. Students in the intervention group exhibited behaviors that pointed to greater persistence when compared to the students in the control group. This is evidenced in the field notes by phrases such as "John asked for help six times on the same problem today" and "Mylah asked me to pull up a chair so I can help her get through the problem". The teacher-researcher indicated in the field notes that any given point in time during the lesson in the intervention group there were multiple (three/four) hands up for questions whereas in the control group there were long periods of time where no questions were asked. Students in the control group exhibited behaviors to point to putting forth less effort towards solving mathematical problems. Observations such as "I had to ask four students to put their heads up today" and "Two girls only had one of 24 problems solved on the guided practice today" highlight the lack of effort put forth by some students during a traditionally taught mathematics class. The teacher-researcher noted that there were more instances of class discussion during the traditionally taught class, while there were more instances of one-to-one help during the class implementing ALEKS software.

So students in the intervention class showcased higher behavioral engagement when compared to students in the control group. They interacted more with the teacher-researcher and were less likely to give up on their work.

Student engagement questionnaires. The student engagement questionnaires collected both quantitative and qualitative data in order to gain insights on how the students described their level of engagement in the lesson. After assigning students how they would rate themselves as being on task on a scale of 1 to 5 with 5 being the best, students had to first elaborate on their level of engagement by justifying why they rated themselves in that manner. In addition, they had to verbalize any distractions they had during the lesson. Lastly, students also had to summarize what was the most important content that they worked on during the specific lesson on that day. Student qualitative responses to their level of engagement comprised of the collective answers to these prompts. Students in the section not utilizing ALEKS instruction also completed the same daily questionnaire on the same day. After analyzing student responses in order to detect common patterns and themes, a common theme that surfaced is the variety of perceptions that students held regarding classroom engagement.

Perceptions regarding student engagement. Both the intervention and the control group used very short phrases to justify why they rated themselves in a certain way regarding their level of engagement. The intervention group verbalized their level of classroom engagement as to how it related to how many topics they mastered during the particular lesson. The justified their statements on why they rated themselves at a certain level of engagement on the questionnaires by saying, “I did my topics”, “My pie graph grew”, and “Some topics were hard”. The control group also had short justification statements when explaining why they rated themselves as they did regarding engagement, but their statements were more general. When asked to justify their level of classroom engagement, many students wrote statements such as “I did what I was supposed to” and

"I listened". Students in the control group verbalized their level of classroom engagement as it compared to how quiet and orderly they were. Five students also used the phrase "I was tired" when rating themselves as not engaged.

Another question that the teacher-researcher asked in the student engagement questionnaires was for students to describe what the content was that they worked on during the lesson. The teacher-researcher asked that question to gain insights regarding the level of student awareness of the content standards that they were mastering during a particular lesson. The students also answered this question in short phrases in both groups, often giving one-word answers. In the intervention group, student answers were, "angles", or "parallel lines", or "segments". Very few answers [2] were as detailed as "I learned to find the value of angles in a triangle" or "I found the measure of vertical angles". Students in the control group used phrases such as "the lesson objective" or "angle problems". All students answered this question in the intervention group, but more students [8] in the control group left this question blank.

So although more students in the intervention group were able to verbalize the content of their learning, evidence shows that students in both groups lacked depth in the descriptions of what they learned during the daily lessons. Furthermore, students displayed disparities in their perceptions of seeing themselves as engaged, and even the quiet students who were not very participatory indicated that they occasionally considered themselves engaged in the lesson.

Concluding ideas. The themes that emerged in the lessons were promoting independence, developing fluency, beliefs about technology, student questioning and student perceptions of engagement. Most students responded positively to learning with the ALEKS technology in that they saw the benefits that it had in individualizing their learning. Most students viewed ALEKS software as having a positive impact on their learning and their statements reveal that they enjoyed using ALEKS while learning geometry. They voiced that utilizing the technology helped them speak up more in class and become more goal-oriented. They recognized the benefits of the software system in being able to generate multiple examples while students are working towards mastery. Additionally, they conceptualized the importance of the knowledge checks in aiding with the retention of knowledge, since they were forced to relearn topics that they forgot when taking a knowledge check.

Although all students in the intervention group did not express the same feelings towards using technology as part of the learning process, they all expressed that they benefited as learners through utilizing ALEKS as part of their learning experience. Students were able to recognize their weaknesses as math students in that they lose focus or forget concepts easily. But they also expressed the important role that the software had in helping them retain concepts while continuing to reach for their learning goals.

Data Triangulation

The quantitative and the qualitative data of this research study were combined in order to triangulate the findings and provide enhanced understanding of the data. Data triangulation helps validate research findings through the use of multiple methods and sources of data collection (Mertler, 2017). Each method provided insight as to how utilizing ALEKS affects student achievement, self-efficacy, attitudes and student engagement.

Quantitative data suggested that utilizing ALEKS software over the period of six weeks as part of mastering geometry concepts has a significant impact on student achievement, but it does not have any more significance than the traditional instruction did in the control group. Scores on both the unit assessments indicate that although students in the intervention group that utilized ALEKS software did perform better than students in the control group, these differences were not statistically significant. Responses on the self-efficacy questionnaires point to ALEKS positively impacted the self-efficacy of students. The results showed that students believe that they can understand, enjoy, and learn mathematics better after utilizing the software program for six weeks. In addition, questionnaire responses indicate that students possess increased beliefs that they can not only *do* the mathematics required in their geometry course but they are also *good* at mathematics. Student responses on the student attitude surveys indicate that students enjoy mathematics more and are more comfortable with using technology as part of learning. Students indicated that they are more interested in mathematics, more confident, and less nervous when solving a mathematics problem. Some of the student responses pointing to negative shifts in attitudes towards learning indicate that students continue to struggle with the subject of mathematics. Some of the negative shifts in attitudes point to that students get more anxious in school and voice a growing dislike of school. So incorporating the software ALEKS may have highlighted an increased disliking of mathematics and school in general. This could be due to the fact this group of students has historically found the subject of mathematics challenging as evidenced by their low grades in prerequisite courses. Uchida and Mori (2018) suggest that there is a causal chain connecting a dislike for mathematics and poor mathematics achievement. So it is possible that the students' dislike of the subject is not indeed due to the intervention but due personal perceptions derived from their historical struggle with mathematics.

The qualitative data, which consisted of the student responses during a focus group interview, field notes recorded by the teacher-researcher during semi-structured observations, and student engagement questionnaire responses gave further insight as to how ALEKS affected student attitudes toward learning. Student responses from the focus group interview validated that students liked using the software and saw value in the ability of the software to help personalize the instruction towards meeting the individual (and diverse) student needs. Students recognized the support that the utilization of ALEKS software provided in helping them develop, master, and retain mathematical concepts.

Both the quantitative data and qualitative data revealed that ALEKS impacted students positively in increasing their belief and confidence that they *can* do the mathematics demanded by the geometry course. Both the field notes and the focus group interview reveal that students utilizing the software asked a greater amount of questions and interacted more with the teacher-researcher during the allotted class time. Students in the intervention group were more confident in asking questions, since they recognized that no one else in the class could hear or make negative comments regarding the difficulties that they encountered.

So ALEKS has an overall positive effect on student achievement, self-efficacy, and engagement of 11^{th} grade geometry students. The intervention group utilizing ALEKS had slightly higher scores both of the two instructional units, but this fact alone is not enough to confirm that a difference indeed exists and needs further investigation. ALEKS can help increase the mathematical self-efficacy of students by increasing their beliefs that they can learn, understand, and enjoy mathematics more. Utilizing ALEKS as a part of instruction in geometry can help increase the engagement of students through enabling them to be more actively involved in their learning. The software can allow students to continue to practice mastering mathematical concepts, while simultaneously holding private conversations with their teacher regarding their concerns and misconceptions. Students can become more independent as learners, as utilization of the software can help increase their goal setting practices while allowing them to work at their own individualized level and speed. ALEKS can have a mixed effect on student attitudes and further exploration needs to occur in this area in order to fully understand the impact of this software on student attitudes towards learning. Although ALEKS can help students see the value of technology when learning mathematics and possibly even increase their interest, it can also increase the dislike for the subject and for school itself. So ALEKS can be a learning tool inside the student's toolbox throughout their mathematical journey, and just like with any tool, it should be used with aim, purpose and craft in order to achieve its maximum capabilities.

Summary

During the six-week data collection period, quantitative and qualitative data were collected in order to investigate the effects of ALEKS on student achievement, self-efficacy, attitudes and engagement. Quantitative data were collected in order to provide insight on how utilizing ALEKS affects the achievement of students on the two instructional units. Students' mastery and retention of geometry concepts was assessed through two pre- and a post-tests consisting of 32 questions each that directly aligned with the South Carolina course standards for geometry. The growth between pre- and post-test on two summative unit assessments was measured and statistically analyzed. Results of the dependent *t* test showed that the differences in the means of the two assessments between the groups were not statistically significant. In turn, the teacher-researcher concluded that ALEKS did not have a significant impact on the ability of students to apply geometry theorems in mathematical contexts. Quantitative data were also collected to assess the impact of ALEKS on the self-efficacy of students and the attitudes they held towards learning. Student responses from the intervention group indicate that students perceive themselves as being able to learn, understand, and enjoy mathematics more after utilizing the software for the six-week period. In addition, they have a greater interest in learning mathematics, and they enjoy utilizing technology as part of their instruction. The negative shifts in student attitudes reveal that students continue to struggle when learning mathematics while sustaining a dislike for the subject and any interaction involving their peers during math class. Qualitative data were collected in order enable participants to verify and triangulate the findings. Through utilizing thematic analysis, student responses were categorized in the five themes that emerged: 1) ALEKS helped promote independent thinking while individualizing the content and the pace of student learning; 2) The generated practice and assessment questions provided by the software helped students master and retain geometry concepts; 3) Student beliefs towards incorporating technology during instruction are inconsistent; 4) Students utilizing ALEKS asked a greater variety of questions that were deeper in nature, and; 5) Students possessed a skewed sense of the meaning of classroom engagement, often aligning engagement with a quiet, and orderly classroom environment. Perhaps the individualized learning path, reinforced by multiple opportunities to master the content contributed to the students' increased sense of self-efficacy. Perhaps the combination of interacting with the software and the teacher-researcher provided increased opportunities for questions and wonder. The teacher-researcher then simultaneously reviewed both the quantitative and the qualitative data, and found that while students communicated positive responses towards using ALEKS software, the quantitative data indicated that there was no impact on student achievement. The focus group interviews consisted of overwhelmingly positive responses and the significance of these responses will be discussed later in Chapter 5. In addition, Chapter 5 will also discuss the role of the teacher-researcher as a curriculum leader, include an action plan based on the findings of this research, and address implications for further practice.

CHAPTER 5

FINDINGS AND IMPLICATIONS

This chapter gives an overview of the previous chapters, summarizes and discusses the findings of this study, and explores implications of these findings for educational practice. The final reflections included in this unit include an overview of the problem of practice, the research design summary, the role of the teacher-researcher as a curriculum leader, implications of future research, and implications of this study on academic practice framed within the premise of action research.

Problem Statement

A prevalent Problem of Practice at Achieve High school is that the majority of students at struggle in retaining the mathematics we teach them. While the End-of-Score Algebra 1 examination scores showed that only 43% of students passed the Algebra 1 EOC, the Measures of Academic Progress (MAP) assessment at the beginning of the year showed that 60% of students scored below the 9th grade level mean score. Students who have weak Algebra 1 foundations have a detrimental effect on the strength of the overall mathematics program, as lack of strong mathematical foundations, motivation, or both have led to the majority of students opting out of even attempting the pre-calculus course as their capstone math course. Forty-five percent of students have either a D or an F as a final grade in Algebra 2 and thirty-nine percent of students have either a D or an F as a final grade in geometry. While there were 228 students attempting an Algebra 1 unit in the ninth grade, there were only 62 students attempting a pre-calculus credit as seniors.

Embedded within that huge problem of failure to retain information lies the specific problem of practice for Achieve High school of high failure rate for geometry classes; this further points out the intersection of low mathematical ability with the lack of motivation or engagement to reach mathematical solutions.

Purpose Statement

The purpose of this proposed research study was to measure the effects of intelligent tutoring software on the achievement, self-efficacy, attitudes, and engagement of geometry students. The overarching goal was to increase mathematics achievement and help students develop a positive attitude towards mathematics. The long term school-wide goal is to strengthen the algebraic foundations of Achieve High School's geometry students while increasing the number of seniors enrolled in the pre-calculus course. Through increasing mathematics achievement and improving the disposition of students towards mathematics, Achieve High School is committed to decreasing the failure rate of all mathematics classes, but specifically the failure rate of geometry.

The literature suggests that using different technologies in the mathematics classroom has shown improvement in student attitudes toward learning, higher achievement, and improved engagement with mathematics (Avci, Keene, McClaren, & Vasu, 2015). Intelligent tutoring software systems attempt to address issues with motivation that face schools today through adapting instruction to learners' prior knowledge, personal preferences, and need for timely assistance (Walkington, 2013). Additionally, the literature review indicated research was needed on the use of this technology in a high school setting. This proposed research study investigated the impact that adaptive learning technologies have on retention of mathematical concepts along with motivation and engagement of 11th grade geometry students.

Research Questions

This action research study sought to describe the effects of ALEKS, an intelligent tutoring software system, on high school students' achievement, self-efficacy, attitudes, and engagement. The research questions are:

1. What are the effects of ALEKS on 11th grade geometry students' skills of applying geometry theorems in mathematical contexts?
2. What are the effects of ALEKS on self-efficacy of 11th grade geometry students?
3. What are the effects of ALEKS on student attitudes of 11th grade geometry students?
4. What are the effects of ALEKS on student engagement of 11th grade geometry students?

Methodology

In order to explore and analyze the effects of ALEKS on student achievement, self-efficacy, attitudes, and engagement, the current research study implemented action research methodology. Action research involves a systematic inquiry into one's own practice and is conducted by teachers for themselves (Mertler, 2017). The teacher-researcher used a convergent mixed-methods design that consisted of a concurrent analysis of quantitative and qualitative data (Creswell, 2012). This study implemented a pretest-posttest control group design, where one of the geometry classes was assigned the intervention (ALEKS software usage) and the other geometry class served as the control group and was taught utilizing standards-based, traditional instructional methods. In order to address the research questions more comprehensively, the teacher-researcher collected data that would measure and interpret the effect of ALEKS on student achievement, self-efficacy, attitudes, and engagement of 11th grade geometry students. In a mixed-methods design, quantitative data provides information that can be analyzed statistically, while qualitative data provides opportunities for individuals to express their own opinions and perspectives (Mertler, 2017). The convergent mixed-method design complemented this study in that it allowed the teacher-researcher to gain deeper insights on academic performance, personal beliefs, and unique perspectives of her own students.

Researcher Role

The researcher role in the action research study was as the classroom teacher for two 11th grade geometry sections. The duality of the role as a teacher and as a researcher put her in the heart of this research study, serving both as an insider throughout the process and an outsider throughout the analysis and reflection phase. As a teacher, the role of the teacher-researcher was to implement ALEKS software with the group receiving the intervention and to provide rich, standard-driven lessons for the group that was utilizing ALEKS. She ensured that both groups kept the same pace and the needs for differentiation were met in both groups, regardless of the fact that they did not have access to ALEKS. Holding the role of a participant enabled the teacher-researcher to personally experience the student reactions as they interacted with the software. It also allowed her to connect with the participants by answering their questions and providing guided explorations in order for them to reach solutions.

The teacher also served as a researcher, which allowed her to collect and analyze data and reflect on the findings of the study. Student achievement was measured through pre- and post-tests of the two geometry units. The teacher-researcher also collected other quantitative data through the initial and final self-efficacy questionnaires, student attitude surveys, and student engagement surveys. As a researcher, she interviewed the students in a small focus group in order to gain a deeper understanding on their experiences and perceptions while utilizing ALEKS. The teacher also recorded field notes for the duration of the timeframe of this research in both the intervention and the control group. Lastly, the teacher-researcher ensured anonymity of students by assigning pseudonyms prior to the start of any of the analysis and discussion of the study.

Site and Participants

This study took place at Achieve High School is a rural high school of 1,374 students. The school has a demographically diverse population with 1% Asian, 2% two or more races, 39% Caucasian, 8% Hispanic, and 49% African American (S.C. Department of Education, 2016). The poverty index of AHS is high with 70% of the students are receiving free/reduced lunch. The school has a student to teacher ratio 26:1 in core subject classes and 53% of its faculty members hold advance degrees (S.C. Department of Education, 2016). The school follows a 4 x 4 block schedule while the ninth-grade students belong in the ninth-grade academy and have year-long English, mathematics, and social studies classes that are 55 minutes in length. All of the remainder of the classes are 90 minutes long and they meet 5 days a week for 90 days.

The participants of this study were 45 11^{th} grade students enrolled in college preparatory geometry led by the teacher-researcher. This was a convenience sample of 45 students taught by the teacher-researcher, and they were divided in two separate classes. This was an ethnically diverse group, where 23 students are African American, 12 are Caucasian, nine are Hispanic, and one is multi-racial. There were 19 males and 24 females. Seventy-one percent of students (n=32) were receiving free or reduced lunch at school (data retrieved from PowerSchool, 2016). There were two students that understand minimal English (level 1 proficiency) and chose to work the ALEKS software in the Spanish language. Eight students had an Individualized Education Plan that addresses accommodations due to various learning disabilities. Sixty-four percent of students (N=29) had previously earned a D or a C in the prerequisite course of Algebra 1 and twenty percent of students (N=9) are repeating geometry for the second time.

Data Collection Procedures

The current action research study incorporated a convergent mixed-methods design. Quantitative data was collected through pre- and post-tests of two geometry units, self-efficacy and student attitudes questionnaires and student engagement surveys. The pre- and post-tests of the two geometry units were given in order to determine how well students are applying the geometry theorems in mathematical contexts. The teacher-researcher conduced the pre- and post-intervention questionnaires on self-efficacy and student attitudes in order to determine changes in student self-efficacy or their attitudes toward learning. Qualitative data was collected through a semi-structured focus group interview, field note analysis and student engagement questionnaires. The interview was recorded and transcribed, and all qualitative data was coded in order to detect patterns and emerging themes.

Results

The teacher-researcher triangulated the data in order to draw accurate and valid conclusions, and in order to equally combine the strengths of each form of data (Mertler, 2017). While there was a slight difference in the mean scores of the two Geometry unit assessments between the intervention and the control group, this difference is not statistically significant. The intervention group utilizing ALEKS software had a mean that was approximately five points higher as a group when compared to the group not utilizing ALEKS; this, however, did not prove to be significant when doing a dependent two-tailed *t*-test. Results of student self-efficacy surveys showed an average increase in the self-efficacy of students utilizing ALEKS software. Highest gains in self-efficacy were found in the increase in the beliefs of students that can understand, enjoy, and learn mathematics better after utilizing the software program for six weeks. Analysis of student attitude surveys point to that students displayed mixed results regarding the impact of ALEKS on their attitudes towards learning. They seemed to express some positive shifts in attitudes while learning with ALEKS (such as enjoyment in using a computer while learning and having an increased interest in math), but students also voiced a dislike for mathematics and for school. It is uncertain whether the dislike for mathematics is a result of poor achievement or the cause of it, as disliking math is a suitable excuse for not studying and aiming for personal improvement (Uchida & Mori, 2018). Students could have possibly expressed disliking school more due to the fact that they were already challenged by mathematics as indicated by prior poor performance in prerequisite courses. Utilizing ALEKS forced students to work solely and actively on their individualized areas of mathematical weaknesses, which could possibly increase their dislike for the subject.

Qualitative data was collected in order to highlight a deeper understanding of student perceptions and beliefs. Qualitative data was collected through semi-structured interview with seven participants, student engagement questionnaires, and field notes. Student perceptions of ALEKS were voiced during the interview, and they were categorized and expressed through thematic analysis, which highlighted three themes: 1) Promoting independence; 2) Developing fluency and; 3) Beliefs about technology Promoting independence addressed the ability of the students to learn at their own pace while becoming advocates for their own learning. Developing fluency addressed the structure of the software system ALEKS and how this structure helped students master and retain mathematics. Beliefs about technology addressed the student reactions to incorporating technology while learning mathematics. Additional themes emerging form the qualitative analysis include the nature of questioning by students, and their perceptions regarding student engagement. The analysis of the field notes revealed that a great disparity existed between the quantity and the quality of questions asked by the students in the ALEKS classroom versus the traditional classroom. Students in the ALEKS classroom asked not only asked more questions throughout the duration of the class, but their questions were deeper and more content focused. The type of questions they asked evidenced not only that they evaluated their own mathematical processes, but they were gaining a deeper understanding of the content. Students in the control group asked fewer questions that were broader in context, often asking the teacher-researcher to explain how to proceed with a solution or how to get started solving a geometry problem.

The results point to that ALEKS can impact a student positively if utilized when learning geometry. By increasing the student's independence in choosing their mathematical topics, ALEKS helps put the pace and depth of learning in the control of the student. ALEKS software works on building up the confidence of the student by allowing the student to truly believe that they *can* do the mathematics required of them and that they *can* be successful in this current course. Although the impact of ALEKS on academic performance may be comparable to that of traditional teaching methods, utilizing this software can increase student belief and perceptions in their mathematical abilities.

Curriculum Leader Role

Serving as the mathematics coach at Achieve High School has placed the teacher-researcher in the heart of curriculum leadership. The teacher-researcher brings content and pedagogy experience to the school's leadership team in order to strengthen the organization as a whole. She aims to continue developing within the five functions of an instructional leader, which are visioning, modeling, coaching, managing, and mediating (Tschannen-Moran, 2013). The teacher-researcher employs a transformational leadership style, one that constantly aims at encouraging, inspiring and motivating her colleagues in order to create change. Transformational leadership has been found to be consistently related to organizational and leadership effectiveness (Valeriu, 2017). This type of leader needs to be patient and tenacious, as truly transforming an organization takes time and effort on all of its constituents. Brubaker (2004) claims that transformational leadership inspires followers around the vision of the organization and creates lateral relationships where everyone feels the accountability and sees themselves as a pivotal member of the whole group. The teacher-researcher views her ongoing, open collaboration with the mathematics department as a key component in the professional growth and development of teachers. She works at helping the mathematics department embrace a sense of organizational purpose at improving the mathematics program at her school, by strengthening the student foundations and through equipping students with the skills that are necessary for being successful within a more challenging curriculum.

As a curriculum leader, it is imperative that the teacher-researcher models the instructional practices that support student growth and achievement, while all along representing the ideals of a positive school culture. One of the major focus areas of professional development that the teacher-researcher will continue to oversee within her department is the implementation of instructional technology within the mathematics classrooms in order to differentiate student learning. In a study conducted by Schacter (1999), results showed that use of intentional computer supported learning environment maximizes student reflection, encourages progressive thought and independent thinking, shows positive gains on assessments, and develops more positive student attitudes. As a curriculum leader, the teacher-researcher plans to lead open conversations with colleagues, students, and their parents, explaining the evolution of this action research study, reflect on its findings, and framing the potential benefits of intelligent tutoring systems to the educational experience of students and to academia as a whole. These actions will help build trust in a school, and trustworthy leadership helps pull everyone in the team towards the same direction (Tschannen-Moran, 2013). Through employing a shared vision of teachers, administration, and other stakeholders, the teacher-researcher will continue to work towards adequately preparing students for the demands of the 21st century society. The teacher-researcher will actively help transform the collective thinking of her mathematics department by fostering an environment of team learning. Being aware of the time that is necessary in order to see changes in an organization, the teacher-researcher must be patient with seeing the results of technology implementation on the instructional program within the mathematics department and within the larger school community.

Action Plan and Implications for Further Practice

The teacher-researcher is given a tremendous amount of trust in curriculum decisions at Achieve High School. Trustworthy leaders view reflection as an integral part of their practice, using their words and actions as part of this reflection process (Tschannen-Moran, 2013). Although financial resources are scarce, the principal funded the use of ALEKS for all 280 Algebra 1 students in the ninth grade during the 2016-2017 school year based on trusting the recommendation of the teacher-researcher. After informal conversations following several months of software implementation with students, teachers, and administrators, they stated that using the software was helpful in helping students stay engaged and learn the content. Further research was then deemed necessary to really determine the effects of the software as part the instructional programs and especially on the academic achievement and self-efficacy of mathematics students. Embracing the cyclical nature of action research, the teacher-researcher chose to investigate the effects of implementation of ALEKS software on her own Geometry students. At the conclusion of this study and after careful examination of the results, the teacher-researcher devised an action plan that will build on the current research findings and expand on the scope and depth of this action research. The steps of this action plan are summarized below and also shown in Figure 1.

After reflecting on the results of the study, the teacher-researcher will share results with students, teachers and administrators upon the completion of this action research. The reflection phase of action research involves recollection and critiquing of what has already happened, which will not only lead to increased understanding but also the designing the next steps (Mertler, 2017). The teacher will then share the results with the district level professional development team in order to share how ALEKS impacted the achievement, self-efficacy, attitudes and engagement of her geometry students. Sharing the results of the study is the activity which helps bridge the divide between research and application, helping the researcher gain insight in the dimensions of the investigation (Mertler, 2017).

For purposes of this action research, mathematics achievement was measured based on student growth between pre- and post-test scores on two geometry units. Although the intervention group performed slightly better than the control group, the dependent *t* test did not show significance at the $p \leq 0.05$ level. The teacher-researcher is curious if this is due to the small sample size (N=45) or due to the small time frame for data collection (six weeks). In addressing the first question of this cyclical reflection phase, the teacher wonders how the use of intelligent software systems can effect students when used for a longer time and with a larger population. Therefore, the next logical step in the action plan includes expanding the implementation of ALEKS software to all the geometry classes in order to increase the number of participants. Students of the current action research study held positive perceptions regarding the use of the software and the confidence they gained in their ability to grow as mathematicians and students. Thus, the teacher-researcher plans to make this software available to all geometry classes in the fall of 2019 while planning to support those geometry teachers in its implementation.

The teacher-researcher believes that current educational practices will be enhanced if students have more exposure to quality interactions with the various online platforms of learning mathematics. Since the teacher-researcher also serves as the mathematics coach at AHS, she will take on the responsibility of composing a team of teachers who will research the various learning technologies available and delineate action steps in exposing students of all grade levels to the grade-level appropriate technologies. This step also includes educating the teachers themselves on how to maneuver through the new technologies and also on how to effectively incorporate technology in their own mathematics classroom. This could be done through school-wide professional development or through offering a district-wide course on implementing technology in the mathematics classroom during the summer professional development institute.

Lastly, this action plan includes addressing the financial restraints that implementing ALEKS software ensues. The predominant weakness of this study is the financial cost associated with purchasing ALEKS software program. Supportive administrators at the school of the teacher-researcher made this purchase possible due to frustration of past EOC scores and lack of consistent student motivation. The cyclical nature of action research, however, will not be possible if future funding is depleted for this purchase. In order to avoid this, the teacher-researcher will meet with the district grant writer and discuss possible grants that will fund a prolonged, more systemic adaptation of ALEKS software. Pending on the available possibilities, the teacher-researcher will also include a fund proposal request in a timely fashion to be included in the principal's school budget proposal for the following school year. If after investigating the avenues listed above the teacher-researcher still feels uncertain about the financial viability of continuing this program, she will apply for a longer pilot license through the ALEKS software company that would include a larger population of students.

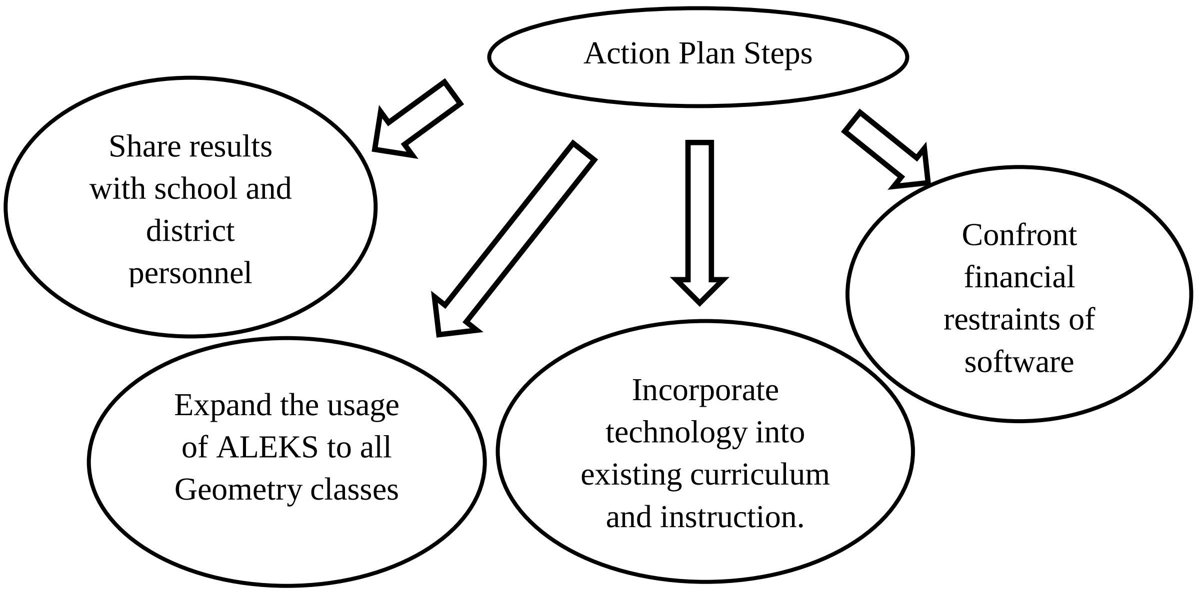


Figure 5.1. Action plan steps delineating implications for further practice.

It is the purposeful selection of these action steps that aims to directly affect the current educational practices. The continuous reflection on how each action step impacts student learning, and for the scope of this research student achievement, self-efficacy, attitudes and engagement, is imperative in order to make a systemic change that will eventually address the current problem of practice.

Implications for Further Research

The role of mathematics coach enables the teacher-researcher to intertwine the cyclical nature of action research with continuous efforts to improve instructional practices at her school. Every moment of analyzing student data and interacting with colleagues serve as opportunities for the teacher-researcher to reflect upon implications of the collective actions of the school as a unit for further research. Upon the reflection of the research findings, the teacher-researcher found herself wondering the following questions:

1) How do student re-conceived notions towards technology affect their learning and how can teachers begin to address a systemic transformation of these perceptions?
2) How can incorporating technology be embedded into existing curriculum current academic support systems?
3) How can the school system as a whole begin to address the financial restraints set in place by the implementation of ALEKS software?

The teacher-researcher identifies the following possible areas as areas of future exploration that could expand of the findings and implications of the current action research study:

- analyzing social justice implications
- investigating student attitudes towards learning with technology
- exploring the impact of the timing of ALEKS software implementation,
- considering utilizing ALEKS as tool for academic support and enrichment
- researching how student pre-conceived notions regarding the role of the teacher

Further research is needed on the above identified areas in order to investigate the effects of intelligent tutoring software systems such as ALEKS on student achievement, self-efficacy, attitudes, and engagement of high school geometry students.

Social justice implications. Exposing all students to ALEKS ensured that all students, regardless of their academic, ethnic or socioeconomic backgrounds, had the same opportunities for growth and academic success. Further research can look into the effects that intelligent tutoring software has on the achievement, self-efficacy, attitudes and engagement of minority student populations. Narrowing the achievement gap takes multi-faceted efforts that need to analyze sources of disparities in achievement, self-efficacy, and student attitudes of minority students as well as students of low socioeconomic backgrounds. This includes implementing rigorous standards, providing a challenging curriculum, and providing extra help to struggling students (Haycock, 2001). The teacher-researcher may choose to implement a qualitative research design, such as a case study, in the future. Qualitative research enables the researcher to build a more holistic, largely narrative description that would enhance understandings through exploring causation or finding underlying principles (Astalin, 2013). An explanatory case study can aid in providing further insights on explaining data patterns such as the gains (or lack thereof) in achievement scores or self-efficacy of minority students while interacting with ALEKS.

Attitudes towards learning with technology. Additional findings of this research study were that students held varied and inconsistent attitudes towards utilizing technology while learning mathematics. This helped frame the question of researching the implication of pre-conceived attitudes of students towards technology and ways to help students conceptualize the importance that technology can play in their education. A next step in the action plan includes investigating and addressing the causes of negative attitudes towards the inclusion of computers while learning mathematics. The teacher-researcher believes that the students who did not respond positively towards technology implementation in mathematics were simply doing so because they had never used a computer as part of an instructional program in math class. They were further along in their educational journey (11th grade), and are used to learning mathematics when a teacher stands and delivers the content.

Timing of the software implementation. This study was conducted at the very beginning of the school year and lasted for the first six weeks of the semester. The characteristics of students between the beginning of the semester and at the end of the semester may differ. For example, students in the beginning of the semester may be more motivated and eager to learn, whereas fatigue may set in after a few weeks and students may lose that drive. Students took the initial self-efficacy and student attitudes questionnaires at the very beginning of the course, where students had a positive outlook on the course and their ability to be successful, as they had not completed any lessons or curriculum assessments. The final questionnaires were given six weeks into the semester, where students may have been possibly beginning to be disappointed about their grades and starting to lose confidence in their ability to be successful. As a result, studies conducted at different times of the semester may yield different results.

Academic support and enrichment. The software ALEKS was utilized during the school day and within the parameters of the timing when students were in class. Continuing research on the impact of ALEKS when used outside the classroom setting needs to continue. ALEKS software has helped students make gains in achievement when implemented in after-school programs and as a supplemental homework component (Craig, Hu, Graesser, Bargagliotti, Sterbinsky, Cheney & Okwumabua, 2013; Hagerty and Smith, 2005; Huang, Craig, Graesser & Hu, 2016). Achieve High School has recently been awarded a grant for an after-school program, lasting for three hours for four days a week. Additional research implementing ALEKS during those hours with struggling students could explore the effectiveness of this software when utilized by students voluntarily. Students are not mandated to attend the homework program but rather choose to go whenever needed. The ability to utilize ALEKS during that time can serve as tool for further academic support in order to meet the differentiated needs of the student. Further research can help investigate the effects of ALEKS on student achievement, self-efficacy and attitudes towards learning when utilized by individual student choice on their own personal time.

Predispositions regarding teacher roles. Another area of future research includes investigating how pre-conceived beliefs regarding the role of the teacher in the classroom affects student achievement when interacting with intelligent tutoring software system such as ALEKS. The teacher researcher realized during the focus group interview that some students equate a direct instruction model of teaching as active learning for all students. Some students continue to hold traditional beliefs that the teacher's role should be simply to share the information he/she knows while students listen and learn. The role of the teacher-researcher when students are interacting with ALEKS was much different, with her role shifting much closer to that of an individual tutor. During class time, the teacher did no direct teaching, but rather listened to independent student questions, redirected student thinking when necessary, and often provided a springboard for learning in order to help students think critically for themselves. This role is foundationally different than the one where a teacher is disseminating information to a wide classroom audience of students. Further studies should be conducted exploring the inherent beliefs of students regarding the role of the teacher, and then analyzing how these beliefs affected their achievement, self-efficacy, attitudes and engagement.

Summary

This study resulted in the collection of quantitative and qualitative data that described the effects of ALEKS on student achievement, self-efficacy, attitudes and engagement of 11th grade geometry students. ALEKS is a type of intelligent tutoring software system that allows for content delivery to be strategically chunked and reinforced through targeted instruction and assessment strategies (Falmagne, Albert, Doble, Eppstein, & Hu, 2013). The study occurred during the fall semester of 2019 in a rural town in South Carolina. The sample consisted of 45 11th grade high school geometry students who were enrolled in geometry. The student participants were divided among two groups, one who implemented ALEKS software as part of their instruction, and the other who served as the control group and was taught using traditional, standards-based instructional practices. The data collection period lasted for six weeks, and the teacher-researcher analyzed both the quantitative and the qualitative data in order to holistically interpret the outcomes. Results of student performance on the two geometry unit assessments show that although ALEKS had a positive effect on student achievement, it was comparable to the group utilizing traditional instructional methods. Further analysis showed that ALEKS had a positive effect on student self-efficacy and level of engagement in learning. Additional findings pointed to students continuing to struggle in mathematics, and while students perceive their interest and confidence levels have improved, they still possess a negative attitude towards school and towards mathematics. The teacher-researcher identified implications of these findings on her current educational practice and how these findings help shape future research efforts. Ultimately, the results of this action research study indicate that incorporating ALEKS software can benefit students. The positive response of students while working with the software as part of their geometry course should inspire educators to further research the effects of intelligent tutoring software systems on the academic and personal success of high school students.

REFERENCES

ALEKS Corporation. (2017). Overview of ALEKS. Retrieved from https://www.aleks.com/about_aleks/overview

Alordiah, C.O., Akpadaka, G., & Oviogvodu, C.O. (2015). The influence of gender, school location, and socioeconomic status on students' academic achievement in mathematics. *Journal of Education and Practice, 6*(17), 130-136.

Anderson, J. R. (1982). Acquisition of cognitive skills. *Psychological Review, 89*, 369–406.

Anderson, J.R., Boyle, C.F., & Reiser, B.J. (1985). Intelligent tutoring systems. *Science, 228*, 456-462.

Anderson, J.R., Corbett, A.T., Koedinger, K.R., & Pelletier, R. (1995). Cognitive tutors: Lessons learned. *The Journal of the Learning Sciences, 42*(2), 167-207.

Anderson, L.W., Krathwohl, D.R., Airasian, P.W., Cruikshank, K.A., Mayer, R.E., Pintrich, P.R., Raths, J., & Wittrock, M.C. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. New York, NY: Longman.

Anderson, J. A., Reder, L.M., & Simon, H.A. (1997). Situative versus cognitive perspectives: Form versus substance. *Educational Researcher, 26* (1), 18–21.

Arasasingham, R., Taagepera, M., Potter, F., & Lonjers, S. (2005). Assessing the effect of web-based learning tools on student understanding of stoichiometry using knowledge space theory. *Journal of Chemical Education, 82*(8), 1251-1262.

Assessment and Learning in Knowledge Spaces. (2017). *ALEKS.* Retrieved from http://www.aleks.com/aboutaleks

Astalin, P.K. (2013). Qualitative research designs: A conceptual framework. *International Journal of Social Science and Interdisciplinary Research, 2*(1), 118-124.

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. In Spence, K. W., & Spence, J. T. (Eds.) *The psychology of learning and motivation* (Volume 2). New York: Academic Press.

Avci, Z.Y., Keene, K.A., McClaren, L.H., & Vasu, E.S. (2015). An exploration of student attitudes towards online communication and collaboration in mathematics and technology. *International Online Journal of Educational Sciences, 7*(1), 110 – 126.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191.

Bandura, A. (1997). Self-efficacy: The exercise of control. New York, NY: Freeman.

Blaylock, T. H., & Newman, J.H. (2005). The impact of computer-based secondary education. *Education, 125*(3), 373-384.

Bloom, B. S. (1968, May). Learning for mastery. *Evaluation Comment, 1*(2). Retrieved from ERIC database. (ED053419)

Borne, A. (2003). Computers and their future use in education. *Futurics, 27*(3/4), 80-82.

Brookstein, A., Hegedus, S., Dalton, S., Moniz, R., & Tapper, J. (May 2011). *Measuring Student Attitude in Mathematics Classrooms*. Retrieved from http://www.kaputcenter.umassd.edu/downloads/products/technical_reports/tr4_ student_attitude.pdf

Brubaker, D.L. (2004). *Revitalizing curriculum leadership: Inspiring and empowering your school community* (2nd ed.). Thousand Oaks, CA: Corwin.

Burns, A. 2005. “Action research: An evolving paradigm?” *Language Teaching, 38*, 57-74.

Carnevale, A.P., Jayasundera, T., & Gulish, A. (2016). America’s divided recovery: College haves and have-nots. Washington, D.C.: Georgetown University Center on Education and the Workforce. Retrieved from: https://cew-632.kxcdn.com/wp-content/uploads/Americas-Divided-Recovery-web.pdf

Chappell, S., Arnold, P., Nunnery, J., & Grant, M. (2015). An examination of an online tutoring program’s impact on low-achieving middle school students’ mathematics achievements. *Online Learning 19*(5), 37-53.

Craig, S.D., Hu, X., Graesser, A.C., Bargagliotti, A.E., Sterbinsky, A., Cheney, K.R., & Okwumabua, T. (2013). The impact of a technology-based mathematics after-school program using ALEKS on student’s knowledge and behaviors. *Computers & Education 68*, 495 – 504. doi:10.1016/j.compedu.2013.06.010

Creswell, J. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Upper Saddle River, NJ: Pearson Education.

Dana, N.F. & Yendol-Hoppey, D. (2014). *The reflective educator’s guide to classroom research* (3rd ed.). Thousand Oaks, CA: Corwin.

Darling-Hammond, L. (2007). Keeping good teachers. Why it matters, what leaders can do. In Ornstein, A.C., Pajak, E.F., & Ornstein, S.B. (Eds.), *Contemporary Issues* *in Curriculum* (pp. 139-146). Boston, MA: Pearson.

Davis, M.R. (2011, April 4). Making math connections. *Education Week, 4*(2), 38.

Desilver, D. (2017). U.S. students' academic achievement still lags that of their peers in many other countries. Pew Research. Retrieved from http://www.pewresearch.org/fact-tank/2017/02/15/u-s-students-internationally-mathscience/.

Dewey, J. (1938). *Experience and education*. New York, NY: Kappa Delta Pi.

Doignon, J.P., & Falmagne, J.C. (1999). *Knowledge spaces*. Heidelberg, Germany: Springer Verlag.

Donovan, L., Hartley, K., & Strudler, N. (2007). Teacher concerns during initial implementation of a one-to-one laptop initiative at the middle school level. *Journal of Research on Technology in Education, 39*(3), 263-286.

Driscoll, M. P. (2005). *Psychology of learning for instruction*. Boston, MA: Pearson.

Dye, J.J. (2007). Meet Generation C. *Econtent*, *30*(4), 38-43.

Epper, R. M., & Baker, E. D. (2009). Technology solutions for developmental math: An overview of current and emerging practices. *Journal of Developmental Education, 26*(2), 4-23.

Ertmer, P.A., & Newby, T.J. (1993). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly 6*(4), 50-72. doi: 10.1111/j.1937- 8327.1993.tb00605.x

Evans, G. W., Gonnella, C., Marcynyszyn, L. A., Gentile, L., & Salpekar, N. (2005). The role of chaos in poverty and children's socioemotional adjustment. Psychological Science, 16, 560 –565. http://dx.doi.org/10 .1111/j.0956-7976.2005.01575.x

Falmagne, J.C., Albert, D., Doble, C., Eppstein, D. & Hu, X . (2013). *Learning Spaces*: *Applications in education*. New York, NY: Springer.

Farmer, T., Leung, M., Banks, J., Schaefer, V., Andrews, B., & Murray, R. (2006). Adequate yearly progress in small rural schools and rural low-income schools. *Rural Educator*, *27*(3), 1-7.

Fine, A., Duggan, M., & Braddy, L. (2009). Removing remediation requirements: Effectiveness of intervention programs. *Primus*, *19*(5), 433-446.

Friedrich, R., Peterson, M., & Koster, A. (2011). The rise of Generation C. Strategy+Business. Retrieved from http://www.strategy-business.com/article/11110?gko=64e54

Friedman-Krauss, A.H., & Raver, C.C. (2015). *Does School Mobility Place Elementary School Children at Risk for Lower Math Achievement? The Mediating Role of Cognitive Dysregulation. Developmental Psychology, 51*(12), 1725-1739.

Fredericks, J.A., Blumenfeld, P.C., & Paris, A.H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*(1), 59-109.

Gilbert, M.C., Musu-Gillette, L.E., Woolley, M.E., Karabenick, S.A., Strutchens, M.E., & Martin, W.G. (2014). Student perceptions of the classroom environment: Relations to motivation and achievement in mathematics. *Learning Environments Research, 17*(2), 287-304.

Gillard, J., Robathan, K., & Wilson, R. (2012). Student perception of the effectiveness of mathematics support at Cardiff University. *Teaching Mathematics and its Applications, 31*, 84-94.

Goals 2000: Educate America Act, H.R. 1804. (1994). Retrieved from http://www2.ed.gov/legislation/GOALS2000/TheAct/index.html

Grenier, J. (2013). *Narrowing the standardized achievement gap among ethnic subgroups*. (Doctoral dissertation). Retrieved from ProQuest. (https://search-proquest-com.pallas2.tcl.sc.edu/pqdtglobal/docview/1440453217/844585220507414FPQ/11?accountid=13965

Hagerty, G. & Smith, S. (2005). Using the web based interactive software ALEKS to enhance college algebra. *Mathematics and Computer Education, 39*(3), 183-194.

Harasim, L. (2012). *Learning Theory and Online Technology*. New York, NY: Routledge.

Harper, M., & Reddy, A. A. (2013). Mathematics placement at the University of Illinois. *Primus*, *23*(8), 683-702. doi:10.1080/10511970.2013.801378113

Harris, J. B., Hofer, M. J., Schmidt, D. A., Blanchard, M. R., Young, C. Y., Grandenett, N. F., & Van Olphen, M. (2010). "Grounded" technology integration: Instructional planning using curriculum-based activity type taxonomies. *Journal of Technology and Teacher Education, 18*(4), 573-605.

Hattie, J.A.C & Gan, M. (2011). In R. Mayer & P. Alexander (Eds.), *Handbook of research on learning and instruction* (pp. 249-271). New York, NY: Routledge.

Haycock, K. (2001). Closing the achievement gap. *Educational Leadership, 58*(6), 6-11.

Hechinger Report. (2010, April 1). Math achievement: U.S. math education is broken. Retrieved from http://hechingerreport.org/u-s-math-education-is-broken/.

Hrubik-Vulanovic, T. (2013). *Effects of intelligent tutoring systems in basic algebra courses on subsequent mathematics lecture courses*. (Doctoral dissertation).

Retrieved from https://search-proquest-com.pallas2.tcl.sc.edu/pqdtglobal/docview /1531329002/C2224910D5DE4752PQ/1?accountid=13965

Huang, X., Craig, S.D., Xie, J., Graesser, A., & Hu, X. (2016). Intelligent tutoring systems work as a math gap reducer in 6th grade after-school program. *Learning and Individual Differences, 47*(2016), 258-265.

Johnson, C., & Kritsonis, W.A. (2010). The achievement gap in mathematics: A significant problem for African American students. *Doctoral Forum, 7*(1), 1-12.

Kant, I. (1959). *Critique of pure reason*. London: Dent/Everyman.

Kotok, S. (2017). Unfulfilled potential: High-achieving minority students and the high school achievement gap in math. *High School Journal, 100*(3), 183-202.

Kulik, J.A. (1982). Synthesis of research on computer based instruction. *Educational Leadership, 43*, 19-21.

Landis, M. (2008). Improving learning with constructivist technology tools. *I-Manager's journal of educational technology*, *4*(4), 9-15.

Leinwand, S. (2009). *Accessible mathematics*. Portsmouth, NH: Heinemann.

Machi, L.A., & McEvoy, B.T. (2016). *The literature review: Six steps to success*. Thousand Oaks, CA: Corwin.

Martella, R.C., Nelson, R., & Marchand-Martella, N.C. (1999). *Research Methods: Learning to Become a Critical Consumer*. New York, NY: Allyn & Bacon.

May, D.M. (2009). *Mathematics self-efficacy and anxiety questionnaire*. (Doctoral dissertation). Retrieved from: https://getd.libs.uga.edu/pdfs/may_diana_ k_200908_phd.pdf

Mayer, R.E. (2008). *Learning and Instruction* (2nd ed.). Santa Barbara, CA: Pearson.

Mertes, E.S. (2013*). A mathematics education comparative analysis of ALEKS* *technology and direct classroom instruction*. (Doctoral dissertation). Retrieved from https://search-proquest-com.pallas2.tcl.sc.edu/pqdtglobal/docview/1498459337/844585220507414FPQ/8?accountid=13965

Mertler, C. (2017). *Action research: improving schools and empowering educators* (5th ed.). Thousand Oaks, CA: SAGE Publications.

Mintrop, R. (2016). *Design-based school improvement*. Cambridge, MA: Harvard Education Press.

Morrison, G. R., & Lowther, D. L. (2002). *Integrating computer technology into the classroom.* (2nd ed.). Upper Saddle River, NJ: Merrill.

Nandwa, O.M., Wasike, D.W., & Wanjala, T.W. (2015). Influence of instructional practices on secondary school students' achievement in mathematics. *Journal of Education and Practice, 6*(26), 29-36.

National Assessment for Educational Progress. (2015). The nation's report card. Retrieved from: https://www.nationsreportcard.gov

National Center for Education Statistics. (2003). Technology integration, technology in schools: Suggestions, tools, and guidelines for assessing technology in elementary and secondary education. Retrieved from: https://nces.ed.gov/pubs2003/tech_schools/chapter7.asp

National Center for Education Statistics. (2009). *The nation's report card: Mathematics 2009*. Washington, DC: US Department of Education, Institute of Education Sciences.

National Center for Education Statistics. (2014). *The condition of education 2014*. Washington, DC: US Department of Education, Institute of Education Sciences.

National Center for Education Statistics. (2015). *The nation's report card: Mathematics and reading*. Washington, DC: US Department of Education, Institute of Education Sciences.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.

Naismith, L., Lonsdale, P., Vavoula, G., & Sharples, M. (2004). Literature review in mobile technologies and learning. *FutureLab Report, 11*.

Naz, S., Shah, S.M., & Rehman, A. (2016). Gender differences in mathematics: Self-efficacy, belief about intelligence, and academic achievement. *The International Journal of Assessment and Evaluation, 23*(3), 1-9.

Newmann, F. M., Wehlage, G. G., & Lamborn, S. D. (1992). The significance and sources of student engagement. In F. Newmann (Ed.), *Student engagement and achievement in American secondary schools* (pp. 11–39). New York, NY: Teachers College Press.

No Child Left Behind Act of 2001, Pub. L. No. 107-115 Stat. 1425 (2002).

Nwaogu, E. (2012). *The effect of Aleks on students' mathematics achievement in an Online learning environment and the cognitive complexity of the initial and final assessments.* (Doctoral dissertation). Retrieved from https://search-proquest-com.pallas2.tcl.sc.edu/pqdtglobal/docview/1038971358/2AE7D9CA94324BB7PQ/1?accountid=13965

Organisation for Economic Co-operation and Development (2012). *United States: Country note. Results from PISA 2012*. Retrieved from https://www.oecd.org/unitedstates/PISA-2012- results-US.pdf

Pajares, F., & Kranzler, J. (1995). Self-efficacy beliefs and general mental ability in mathematical problem-solving. *Contemporary Educational Psychology, 20*, 426-443.

Peiró G. S., Merma M.G., & Gavilán, M.D. (2014). The integration of values, skills and competences in quality education through the subject "Computer Science". 65 Pennsylvania Department of Education. (2012a). Pennsylvania department of education: Academic achievement report. Retrieved from website: http://paayp.emetric.net/School/Overview/c39/121395103/2829

Phillips, D. C. (1995). The good, the bad, and the ugly: The many faces of constructivism. *Educational Researcher, 24*(7), 5–12.

Piaget, J. (1980). *The psychogenesis of knowledge and its epistemo- logical significance*. In M. Piattelli-Palmarini (Ed.), Language and Learning. Cambridge, MA: Harvard University Press.

Pintrich, P.R., Schunk, D.H. (2002). *Motivation in education: Theory, research, and applications*. Upper Saddle River, NJ: Merrill Prentice Hall.

Platko, R. R. (2011). *An analysis of the effects of an integrated learning system on student achievement in mathematics*. (Doctoral dissertation, University of Kansas). Retrieved from http://www.search.proquest.com.library.aurora.edu/docview/864742574/125D5591A2C64195PQ/1?accountid=26354

PowerSchool Group, LLC. (2005-2016). PowerTeacher [Data file]. Available from https://lancastercsd.powerschool.com/teachers/pw.html

Race to the Top Program Executive Summary. (2009). Retrieved from http://www2.ed.gov/programs/racetothetop/executive-summary.pdf

Riel, M. (2007). Understanding action research. Center for Collaborative Action Research. Available at: http://cadres.pepperdine.edu/ccar/define.html

Ritchie, J., & Bates, T.C. (2013). Enduring links from childhood mathematics and reading achievement to adult socioeconomic status. *Psychological Science, 24*, 1301-1308.

Sagor, R. (2000). *What is action research?* Alexandria, VA: ASCD

Schacter, J. (1999). *The impact of educational technology on student achievement: What the most current research has to say (ERIC Document Reproduction Service No. ED 430537*). Santa Monica, CA: Milken Exchange on Educational Technology.

Scherer, M. M. (1999). Perspectives. *Educational Leadership, 57*(3), 5.

Schmidt, W. H. (2012). At the precipice: The story of mathematics education in the United States. *Peabody Journal of Education, 87*, 133-156. Doi:10.1080/0161956X.2012.642280

Schnoebelen, T.J. (2008). *A case study of a midwestern urban high school's intervention strategy to improve student proficiency in mathematics.* (Doctoral dissertation). Retrieved from ProQuest. (https://search-proquest-om.pallas2.tcl.sc.edu/ pqdtglobal/ docview/304634883/51915C4C150C488FPQ/4?accountid=13965

Schunk, D.H. (1991). Self-efficacy and academic motivation. *Educational Psychologist, 26*, 207-231.

Skinner, B.F. (1968). *The Technology of Teaching*. New York, NY: Appleton-Century-Crofts.

Smith, G.E., Thorne, S., & International Society for Technology in Education. (2007). *Differentiating instruction with technology in K-5 classrooms*. Eugene, OR:

International Society for Technology in Education.

South Carolina Department of Education. (2015, March). *South Carolina college and career standards for mathematics.* Retrieved from https://ed.sc.gov/instruction/standards-learning/mathematics/standards/scccr-standards-for-mathematics-final-print-on-one-side/

South Carolina Department of Education. (2016, March). *South Carolina state report card*. Retrieved from http://ed.sc.gov/assets/reportCards/2015/high/c/h2901008.pdf

Spring, J. (2005). *The American school: 1642-2004* (5th ed.). Boston: McGraw Hill. (Original work published 1994)

Stillson, H., & Alsup, J. (2003). Smart ALEKS…Or not? Teaching basic Algebra using an online interactive learning system. *Mathematics and computer education, 37*(3), 329-340.

Stillson, H., & Nag, P. (2009). ALEKS and MATHXL: Using online interactive systems to enhance a remedial Algebra course. *Mathematics & Computer Education, 43*(3), 239-247.

Taageperaa, M., Pottera, F., & Millera, G. (1997). Mapping students' thinking patterns by the use of the Knowledge Space Theory. *International Journal of Science Education*, *19*(3), 283-302.

Taylor, J. (2008). The effects of a computerized-algebra program on mathematics achievement of college and university freshmen enrolled in a developmental mathematics course. *Journal of College Reading and Learning, 59*(1), 35-53.

Toure-Tillery, M., & Fishback, A. (2014). How to measure motivation: A guide for the experimental social psychologist. *Social and Personality Psychology Compass, 8/7*, 328-341. doi:10.1111/spc3.12110

Trickett, E.J., & Moos, R.H. (1973). Social environment of junior high and high school classrooms. *Journal of Educational Psychology*, *65*, 93-102.

Tschannen-Moran, M. (2013). Becoming a trustworthy leader. In Grogan, M. (Ed.), *The Jossey-Bass reader on educational leadership* (pp. 40-54). San Francisco, CA: John Wiley & Sons.

Uchida, A., & Mori, K. (2018). Detection and treatment of fake math-dislikes among Japanese junior high school students. *International Journal of Science and Mathematics Education, 16*(6), 1115-1126.

U.S. Census Bureau. (2015). *State & county Quickfacts: Lancaster County, S.C.* Retrieved November 25, 2016, from http://www.towncharts.com/South-Carolinea/Demographics/Lancaster-city-SC-Demographics-data.html

U.S. Department of Education. (2012). Definitions. Retrieved from https://www.ed.gov/racetop/district-competition/definitions/.

Valeriu, D. (2017). The significance of emotional intelligence in transformational leadership for pubic universities. *Euromentor Journal 8*(1), 35-51.

VanLehn, K. (2006). The behavior of tutoring systems. *International Journal of Artificial Intelligence, 16*(3), 227-265.

Varsavsky, C. (2010). Chances of success in and engagement with mathematics for students who enter university with a weak mathematics background. *International Journal of Mathematics in Science and Technology, 41*(8), 1037-1049.

von Glasserfeld, E. (1990). An exposition on constructivism: Why some like it radical. In

R. B. Davis, C. A. Maher, & N. Noddings (Eds.), *Monographs of the Journal for Research in Mathematics Education, #4*. Reston, VA: National Council of Teachers of Mathematics.

Vukovic, R. K., & Siegel, L. S. (2010). Academic and cognitive characteristics of persistent mathematics difficulty from first through fourth grade. *Learning Disabilities Research & Practice, 25*(1), 25-38.

Waalkens, M., Aleven, V. & Taatgen, N. (2013). Does supporting multiple student strategies lead to greater learning and motivation? Investigating a source of complexity in the architecture of intelligent tutoring systems. *Computers & Education, 60*, 159-171.

Walkington, C.A. (2013). Using adaptive learning technologies to personalize instruction to student interests: The impact of relevant contexts on performance and learning outcomes. *Journal of Educational Psychology, 105*(4), 932-945.

Webster, J. & Watson, R.T. (2002). Analyzing the past to prepare for the future: Writing a Literature Review. *MIS Quarterly 26*(2), xiii-xxiii

Weiss, I., & Pasley, J. (2004). What is high-quality instruction? *Educational Leadership, 61*(5), 24-28.

Wendel, H. (2016). *Effects of intelligent computer-generated interactive mathematics programs on students' achievements and affective domain* (Doctoral dissertation). Retrieved from ProQuest. (file:///C:/Users/melina.oueini/Documents/Ed.D%20articles%20and%20readings/dip%20aleks.pdf

Yilmaz, B. (2017). *Effects of adaptive learning technologies on math achievement: A* *quantitative study of ALEKS math software* (Doctoral dissertation). Retrieved from ProQuest. (https://login.pallas2.tcl.sc.edu/login?url=https://search-proquest-com.pallas2.tcl.sc.edu/docview/1906301379?accountid=13965)

APPENDIX A

MATHEMATICS SELF-EFFICACY QUESTIONNAIRE

In order to better understand what you think and feel about your high school Geometry course, please respond to each of the following statements on a scale of 1 (Never) to 5 (Usually).

1. I have been able to understand mathematics.	1	2	3	4	5
2. I have done well in my mathematics courses.	1	2	3	4	5
3. I have enjoyed mathematics.	1	2	3	4	5
4. I am the type of person who is able to learn mathematics well.	1	2	3	4	5
5. Mathematics instructors have been willing to help me learn the material.	1	2	3	4	5
6. I have asked questions in my mathematics classes.	1	2	3	4	5
7. I have sought help from mathematics instructors outside of class.	1	2	3	4	5
8. I have set goals in my mathematics classes.	1	2	3	4	5
9. I have worked hard in my mathematics classes.	1	2	3	4	5
10. I regularly do assigned homework in my mathematics classes.	1	2	3	4	5
11. I believe I can do the mathematics in this Geometry course.	1	2	3	4	5
12. I believe I am the kind of person who is good at mathematics.	1	2	3	4	5
13. I believe I can get an "A" when I am in a mathematics course.	1	2	3	4	5
14. I believe I can learn well in a mathematics course.	1	2	3	4	5
15. I believe I can think like a mathematician.	1	2	3	4	5

16. I believe I can complete all of the assignments in this Geometry course.

	1	2	3	4	5
17. I believe I can understand the content in a mathematics course.	1	2	3	4	5
18. I believe I can do well on a mathematics test.	1	2	3	4	5

APPENDIX B

STUDENT ATTITUDE SURVEY

Circle the appropriate responses based on the key below:

0	**1**	**2**	**3**	**4**
Strongly Disagree	Disagree	Neutral/Undecided	Agree	Strongly Agree

1. I think mathematics is important in life. 0 1 2 3 4
2. In previous high school math courses, my math teachers listened carefully to what I had to say. 0 1 2 3 4
3. I learn more about mathematics working on my own. 0 1 2 3 4
4. I get anxious in school. 0 1 2 3 4
5. Technology can make mathematics easier to understand. 0 1 2 3 4
6. I do not like school. 0 1 2 3 4
7. I like math. 0 1 2 3 4
8. I feel confident in my abilities to solve math problems. 0 1 2 3 4
9. In the past, I have not enjoyed math class. 0 1 2 3 4
10. I receive good grades on math tests and quizzes. 0 1 2 3 4
11. When I see a math problem, I am nervous. 0 1 2 3 4

12. I am not eager to participate in discussions that involve math. 0 1 2 3 4

13. I like to go to the board or share answers with peers in math class.0 1 2 3 4

14. I enjoy hearing the thoughts and ideas of my peers in math class. 0 1 2 3 4

15. Mathematics interests me. 0 1 2 3 4

16. I sometimes feel nervous talking out-loud in front of my peers. 0 1 2 3 4

17. I enjoy using a computer when learning mathematics. 0 1 2 3 4

18. When using technology for leaning math, I feel like I am in my own private world. 0 1 2 3 4

19. I am not comfortable using technology in math class. 0 1 2 3 4

The above questionnaire is adapted and modified from Kaput Center for Research and Innovation in STEM education (Brookstein, Hegedus, Dalton, Moniz & Tapper, 2011).

APPENDIX C

STUDENT ENGAGEMENT DAILY QUESTIONNAIRE

The purpose of this questionnaire is to help me understand my research better and your answers will have no effect on your grade.

1A. On a scale of 1 to 5, with 5 being the best, how would you rate yourself as being on-task?

1 2 3 4 5

1B. Why did you rate yourself that way? Please explain ensuring you discuss any distractions.

2A. On a scale of 1 to 5, with 5 being the best, do you feel that you appropriately practiced the skills you were supposed to be working on?

1 2 3 4 5

2B. Why did you rate yourself in that way?

3. What was the most important concept you worked on today and why do you think this is important?

APPENDIX D

ACTION RESEARCH FIELD NOTES FORM

Date:

1.What are the successes of the lesson today?

2. What could have gone better?

3. On a scale of 1-5, with 1 being not engaged at all and 5 being 100% engagement, student engagement today was: 1 2 3 4 5

Why did I rate engagement in that way above?

4.How well did students practice the mathematics skills they were intended to practice?

5.What changes will I make based on today's results?

Other Notes:

APPENDIX E

FOCUS GROUP INTERVIEW QUESTIONS

1. How do you think ALEKS as affected you as a math student in your ability to solve geometry problems?

2. How does working with ALEKS affect your confidence in your ability to solve geometry problems?

3. How does working with ALEKS help you stay on task when learning?

4. What changes have you noticed in yourself or other students with regards to their attitude towards mathematics after working with ALEKS?

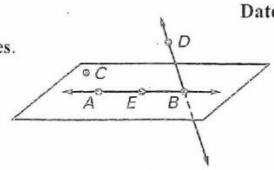
APPENDIX F

UNIT 1 ASSESSMENT

CP Geometry **Unit 1 Test** **Name** ________________

Date ________________

Use the diagram to name the figures.



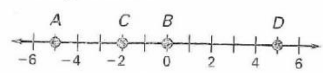
1. Three collinear points.
2. Three noncollinear points.
3. Four noncoplanar points.
4. Two intersecting lines.

Fill in the blanks.

5. A___________ is angle is an angle that measures between 90^0 and 180^0.
6. The __________ is the point that divides a segment into two congruent parts.
7. ________ angles always add up to 90^0.

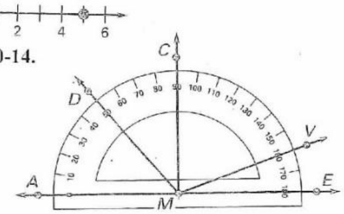
Find the length of the segment below.

8. AB
9. CD



Use the diagram to answer questions 10-14.

10. Find the degrees of <AMC.
11. Find the degrees of <DMV.
12. Find the degrees of <AME.
13. Classify <AMC.
14. Classify <AME.

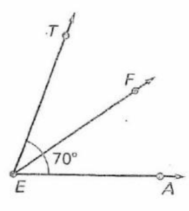


Find the coordinates of the midpoint of a segment with the given endpoints. Then find the length of the segment.

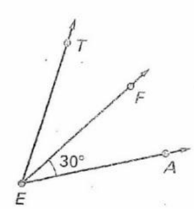
15. A (0, 0) and B (0, 10)
16. C (2, 9) and D (-2, -9)
17. E (4, -8) and F (-6, 6)

In questions 18 and 19, EF is the angle bisector of <TEA. Find the two angle measures not given in the diagram.

18. m<TEF and m<FEA

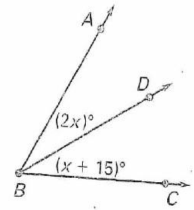


19. m<TEF and m<TEA

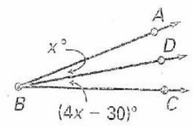


In questions 20 and 21, BD bisects <ABC. Find the value of x.

20.



21.

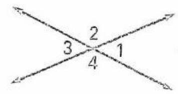


In questions 22-24, use the diagram to solve for the missing angle measure.

22. If m<1=25 then m<3=______

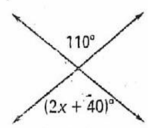
23. If m<2=95 then m<1=______

24. If m<4=130 then m<2=______

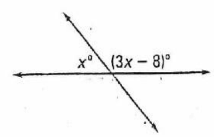


Find the value of the variables in questions 25-28.

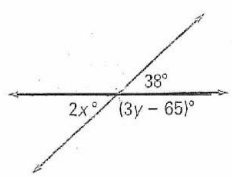
25.



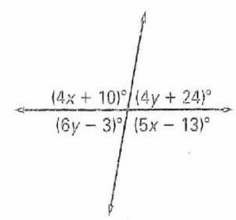
26.



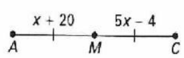
27.



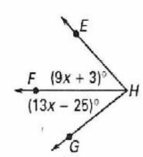
28.



29.



30. Given $m\angle EHG = 77°$



Please answer.

31. Find the complement of a 32^0 angle.

32. <1 and <2 are complementary. If <1=7x+4 and <2=4x+9 find x.

APPENDIX G

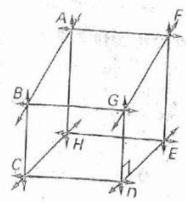
UNIT 2 ASSESSMENT

CP Geometry **Unit 2 Test** **Name** ____________

Date ____________

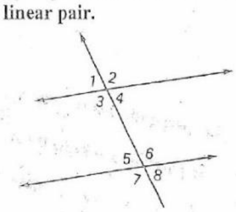
In problems 1-4, use the diagram on the right to complete each statement.

1. $\overleftrightarrow{DE}$ and $\overleftrightarrow{DG}$ are __________.
2. $\overleftrightarrow{AF}$ and $\overleftrightarrow{CD}$ are __________.
3. $\overleftrightarrow{BC}$ and $\overleftrightarrow{DE}$ are __________.
4. Name a plane parallel to plane AHC.



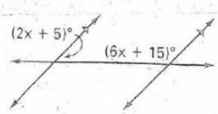
In problems 5-9, decide whether each pair of angles given are alternate interior, alternate exterior, corresponding, same-side interior, or linear pair.

5. <3 and <6 are __________.
6. <4 and <6 are __________.
7. <1 and <5 are __________.
8. <1 and <8 are __________.
9. <6 and <8 are __________.

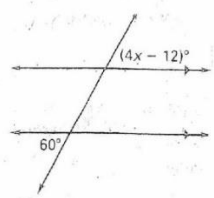


Find the value of x.

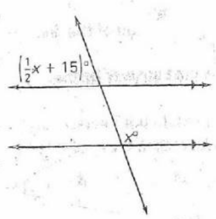
10.



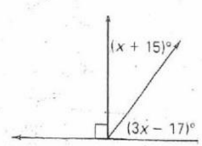
11.



12.

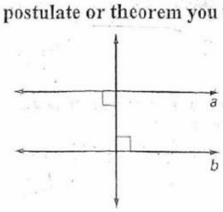


13.

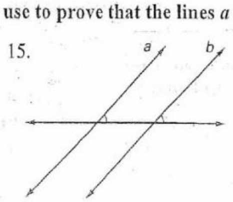


State the postulate or theorem you would use to prove that the lines *a* and *b* are parallel.

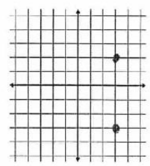
14.



15.



Find the slope of the line that passes through the given points.

16. 

17. E (-1, -2) and F (-6, -4)

Write the equation of the line with the given information.

18. slope 2/3 through (-2, 4).

19. through (4,3) and (-1, 5).

20. parallel to $y = 3x - 6$ through (3, 1).

21. parallel to $y= 2/3x + 1$ with y=intercept -4.

22. perpendicular to $y = -2x - 4$ through (0, -5).

23. through (-3,2) and (1,2).

24. parallel to x=7 through (4, 9).

State whether the lines are parallel, perpendicular or intersecting.

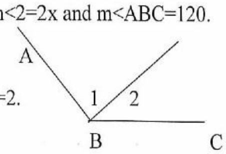
25. $y = -2x+ 4$ and $y = ½ x + 4$

26. $y = 5x + 7$ and $y = 5x – 7$

27. $y = 3x + 6$ and $y = -3x + 9$

Please answer.

28. Find the value of x in the figure on the right. Consider m<1=8x, m<2=2x and m<ABC=120.



29. What is the complement of 48^0?

30. Consider the diagram below. Find AD if BD=12, AC=10 and BC=2.

31. Is (3, -1) a solution to y=3x+ 10?

32. Graph the equations $y = 3x – 1$ and $y = -2x +2$. Decide the relationship between the lines.