THE RELATIONSHIP BETWEEN STUDENT PERFORMANCE ON ALEKS SOFTWARE AND STANDARDIZED TESTS

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ABSTRACT

Educational technology is evolving and growing at a faster pace than ever before. Such fast-paced growth makes it difficult to evaluate and measure its effectiveness in a timely manner and creates a need for independent academic literature in this area. This study serves to address to this need and contribute to the body of literature. The intent of this study is to identify the nature of the relationship between middle school students' progress on ALEKS mathematics software during a school year and their performance on mathematics state assessments. The study is conducted in a Midwest urban charter school with approximately 300 students. This is a quasi-experimental quantitative research design with a sample size of 336 students in grades sixth through eighth between the years of 2015 and 2019. Archived data from these years have been compiled and analyzed using a Pearson correlation and t-test to clarify the nature of the relationship between independent and dependent variables.

APPROVAL PAGE

The undersigned, appointed by the Dean of the School of Graduate Studies, have examined a dissertation titled "The Relationship Between Student Performance on ALEKS Software and Standardized Tests" presented by Elyar Isgandarli, candidate for the Doctor of Philosophy degree, and certify that in their opinion it is worthy of acceptance.

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CHAPTER 1

INTRODUCTION

Technology has found its way into all areas of life, including education. Kirschner and Erkens (2006) described three factors that had an impact on the increase of technology use in education: preparing students for the future workplace, making schools more efficient and/or productive, and reforming education. Similar to the other areas of life, due to various reasons, there are fields within education that may have been affected more than others by the rapid development of technology. Mathematics can be considered one of those fields. More specifically, Hagerty and Smith (2005) claimed that technology's role in mathematics curriculum has increased because of "economic pressures to reduce the cost of education" and "the need for appropriate implementation of accepted educational principles" (p. 183).

One specific type of technological advancement which started gaining extensive attention in the field of education is artificial intelligence (Smith, 2013, p. 51). Artificial Intelligence is a computer program that "imitates human thought process through reasoning" (Smith, p. 51). This type of intelligence has the ability to interact with an individual, based on the prior information collected and stored in its memory. The focus of this study, Assessment and Learning in Knowledge Spaces (ALEKS), is one of the software programs that is being implemented as a part of mathematics curriculum in elementary, middle, high school, and college classrooms. ALEKS is an instructional program that "uses artificial intelligence (AI) to map the details of each student's knowledge" ("Overview of ALEKS," n.d.).

Yilmaz and Caruthers (2017) claimed that a reason for an increase in the use of a certain type of educational technology such as ALEKS is the hope to increase state test scores. Standardized state tests became important for schools with the enactment of the 2001 No Child Left Behind Act because their results were utilized to evaluate the effectiveness of districts, schools, and teachers, and to hold them accountable (LaFerrara, 2013). More recently, Every Student Succeeds Act (ESSA) (U.S. Department of Education, 2017) has a similar focus on accountability through testing. There are many criticisms of standardized testing, such as these tests are harmful to the students' health; in many cases they eventually move to the center of focus; they encourage cheating; and the time spent for their administration can be used more beneficially (Linn, 2001). Standardized tests are also considered standardization efforts and lead to an assumption that the students from diverse backgrounds experience equal opportunities which contradicts the value of diversity (Milner, 2012). Despite these criticisms, accountability through testing remains a part of education that cannot be simply ignored or disregarded. As a consequence, educational technology becomes a convenient tool for districts and schools to integrate into instruction with the hope that it will increase its effectiveness. This in turn would help to improve student learning, close the achievement gap, and prepare students for standardized tests.

Achievement gaps have been a major focus of educators and policy makers for decades and are identified between different groups of students especially based on race and socioeconomic status (Bohrnstedt et al., 2015; Hanushek & Rivkin, 2009). District and school administrators adopt technological tools with the purpose in mind to close these achievement gaps and meet the accountability requirements that are identified by federal and state legislations. New trends in education such as differentiated instruction, multicultural education, culturally responsive pedagogy, and other efforts make educational technology a readily available option for educators at all levels to implement to improve student success.

In the school to be studied in this research, ALEKS was adopted and mandated in 2014 to be implemented as a part of the mathematics curriculum. Test scores in mathematics in this district have historically been way below the state average at the middle school level. For example, in 2018 the percentage of sixth, seventh, and eighth grade students in the state who scored Proficient or Advanced in mathematics was 41.1%, 37.9% and 29.7% respectively. These numbers were 21.4%, 17.4%, and 29.2% in the research site.

Problem Statement

While ALEKS has been adopted in the school that is the site for this study, the relationship between the use of a certain mathematics software and student achievement on standardized tests is unknown or unclear. However, school administrators and teachers invest a great deal of time, effort, and resources towards the successful implementation of this software program. Nwaogu (2012) and Yilmaz and Caruthers (2017) argued the need for the evaluation of such programs and both emphasized that one of the reasons for lack of sufficient objective evaluations is that schools often rely on the companies' advertising about the effectiveness of the programs.

Several articles, case studies, and testimonials can be found on the ALEKS' website that stress the success of ALEKS and its positive effects on math skills, knowledge, and test scores (ALEKS Corporation, 2012a, 2015). According to these articles and testimonials, ALEKS seems to work for different types of schools and student populations around the nation (see Table 1.1).

Table 1.1

Nationwide ALEKS Use for Various Purposes in K-12 Schools

Aquin Jr./ Sr. High School – Gifted and talented, at-risk students, core curriculum
Beachwood Middle School – Improve state test scores, supplement
Big Bear High School – Credit recovery, exit exam, summer school
Charter School of Morgan Hill – Intervention, college and career readiness
Eastern Hancock Middle School – Special education
Haas Elementary School – After school
Oliver Elementary School – Response to Intervention (RtI), enrichment
S. F. Austin Middle School – ESL students

As noted, these case studies and testimonials ranged from middle and high schools to academies and in all regions of the country. The focus on the case studies appeared to be on struggling students and turnaround schools.

However, a search related to the effectiveness of ALEKS in independent literature at the middle and high school levels identified only a small numbers of research studies. For example, a combination of various databases such as Academic Search Complete, EBSCO, JSTOR, Google Scholars, and so forth revealed only five scholarly and peer reviewed journal articles that were related to math and had the word "ALEKS" in their titles. Of those five studies, only one was conducted at the K-12 level. The lack of a sufficient number of studies at this level contributes to the adoption of programs that are based on articles and testimonials published by ALEKS which are likely to be biased and misleading (Li & Ma, 2010).

As stated above, studies that were related to the implementation of ALEKS at the middle or high school levels are limited; however, a number of studies have been conducted at the college level (Canfield, 2001; Hagerty & Smith, 2005; Nwaogu, 2012; Smith, 2013; Stillson & Alsup, 2003; Stillson & Nag, 2009). These studies show mixed results regarding the effects of ALEKS on students' performance. One study concluded that the students who used ALEKS demonstrated significant improvement (Hagerty & Smith, 2005). This study included 251 college algebra students who took pre- and post-tests in eight different sections, four of which were taught using ALEKS and the other four with traditional instruction. The students in the treatment group that used ALEKS outperformed the students in the control group that did not use this program (Hagerty & Smith, 2005).

A second study conducted at the college level also found that "ALEKS had a significant effect on students' mathematics achievement" (Nwaogu, 2012, p. 90). There were 16 students in each of the five sections of a College Mathematics I course for a total of 80. Only 59 of these students took both pre- and post-tests. ALEKS was used as the primary source of instruction in this study, and a t-test was conducted between the pre-test and post-test scores that found a significant difference of 34.55 ($t(55) = -12.256$, $p < .001$).

A third study compared ALEKS to another mathematics software called MathXL and did not find a significant difference (Stillson & Nag, 2009). ALEKS was used from Fall 2001 until Spring 2006, and MathXL was used in Fall 2006 for Basic Algebra courses at the university where this study was conducted. Researchers conducted three t-tests between Fall 2005 and Fall 2006 Unit Exams I, II and Final Exam scores. No sufficient evidence was found to show that one software was better than the other. Other studies at the college level reported positive impact or positive feedback by students and instructors but not significant results (Canfield, 2001; Smith, 2013; Stillson & Alsup, 2003).

Several after-school programs have used ALEKS; however, these programs did not show gains in mathematics. ALEKS software was used as a treatment in a middle school after-school program (Craig et al., 2013). The researchers compared the state test scores of 253 sixth grade students before and after the use of ALEKS. The study did not find a significant difference between the scores of students who used ALEKS versus those who did not use ALEKS.

The unknown relationship between the use of specific mathematics software and student achievement on standardized tests is likely to impact education in multiple different ways, resulting in administrators who make uninformed decisions when adopting educational technologies (Yilmaz & Caruthers, 2017). Secondly, students may be spending their time on software programs that do not increase their learning (Lytras & Pouloudi, 2001). Also, administrators may be spending taxpayer dollars on implementing software programs that may not increase student learning (Yilmaz & Caruthers, 2017). Uninformed decisions regarding a relationship between a certain educational technology and student achievement lead administrators to base their decisions on non-academic materials. In a meta-analysis of the effects of computer technology on student achievement, Li and Ma (2010) argued that “unpublished documents tend to overestimate the impact of technology on the learning of mathematics” (p. 234). Li and Ma (2010) examined 46 studies that involved more than 35,000 learners and found positive effects of computer technology on mathematics achievement. In contrast, Lim et al. (2013) asserted that “schools may not have reaped as much benefit from the use of modern technology” as the other industries (p. 61). They identified a usage and an outcome gap between the regular technology and educational technology and stated that the latter is much less than the former in terms of usage and outcome. In short, the literature is inconclusive regarding the benefits of such software, and it cannot be said that the schools today are more financially efficient and academically effective than the schools before (Lim et al., 2013).

Hence, the number of independent studies that are conducted to evaluate this relationship is limited. School administrators and teachers invest a great deal of time, effort, and resources towards the successful implementation of ALEKS or this type of software without evidence that the program will increase math achievement. The concern about the lack of sufficient independent evaluations of this specific mathematics software can be generalized to educational technologies as a whole. The changes in the field of technology are rapidly expanding to the extent that academic research cannot keep up with the pace (Yilmaz & Caruthers, 2017). In one study, King et al. (2016) identified rapid change as one of the barriers to the effective evaluation of educational technology. The researchers reviewed realist evaluation and "provide[d] an edtech realist evaluation framework" that can be used to effectively evaluate educational technology (p. 37). Carle et al. (2009) reported that "little systematic, scientifically rigorous research evaluates the effectiveness of technological contributions…" in education (p. 376). The researchers conducted a quasi-experimental study with 25 undergraduate students enrolled in two sections of a psychology class. One of the sections, the treatment group, was a technology-enhanced classroom. This study reported a significant difference between regular and technology-enhanced classrooms in student engagement and achievement (Carle et al., 2009). When compared to the present study on ALEKS, the main shortcomings of this research were that it was conducted at a university level, in a psychology class with a small sample size versus a middle school mathematics class with a relatively larger sample size.

This study was designed to use middle school data to provide an alternative resource to ALEKS' funded studies and to provide guidance for district and school administration during the decision process regarding the adoption of ALEKS. The concerns about the use of technology in education have been raised by scholars in general. Kirschner and Erkens (2006) reported that "research reveals that new technologies are often oversold and underused" (p. 200). The goals, such as preparing students for the future workplace, making schools more productive, and reforming education are yet to be achieved (Kirschner & Erkens, 2006). Achieving these goals is a big responsibility that falls on the shoulders of school leaders; thus, it is important for leaders to make decisions based on research. So far, educational leaders are not able to draw from a number of independent studies conducted on ALEKS. For this reason, a gap of independent research on ALEKS at middle and high school levels is concerning. By attempting to identify the nature of the relationship between ALEKS and student performance on standardized tests, this research will contribute both to the body of literature on ALEKS and on educational technology in general.

This project is important to the researcher because he used ALEKS in the classroom for a short period when he was a mathematics teacher. The researcher did not get to see or measure the impact of ALEKS over his students. However, his experience when he used it was positive. He has also had many conversations with other mathematics teachers who did not like using it. Conflicting personal data created a curiosity to study the nature of the relationship between ALEKS and student performance which led to this project.

Purpose and Research Questions

The purpose of this quasi-experimental, correlational study was to identify if there is a relationship between middle school students' ALEKS progress throughout the year and their performance differences on the two mathematics state tests, before and after ALEKS, in a Midwest urban charter school. In quasi-experimental studies, the participants are not randomly assigned to groups (Creswell, 2013). Mark and Reichardt identified four types of quasi-experimental studies: one group pre-test-post-test; nonequivalent group; interrupted time series analysis, and regression discontinuity (2004). Since this study's aim was to find the correlation between ALEKS progress and state test performance of one group of students, it fell under the first type of quasi-experimental research, one group pre-test-post-test.

To identify how ALEKS's use is related to students' performance on standardized tests, this study addressed the following research questions:

1. Is there a correlation between students' progress on ALEKS and their performance on standardized tests, before and after the implementation of ALEKS, at the middle school level?
2. Does a higher completion percentage on ALEKS increase the probability of scoring Proficient or Advanced on a state test?

The null hypotheses formed to tackle these questions were:

$H_{01:}$ There is no significant correlation between students' progress on ALEKS and their performance on the two standardized tests, before and after the implementation of ALEKS, at the middle school level.

$H_{02:}$ Mastering more topics on ALEKS does not increase students' likelihood of scoring Proficient or Advanced on a state test.

Significance of the Study

The goal was to find if there is a significant difference when using ALEKS. This is important because administration and staff must devote a lot of resources, effort and time to its use. Extra computers, iPads and Chromebooks are purchased to accommodate its implementation. A considerable amount of time is spent to train staff, process and analyze data, conduct meetings with teachers, and monitor student progress (Yilmaz & Caruthers, 2017). Sometimes the students who are not progressing are asked to attend extra ALEKS sessions after school and on Saturdays.

The need for the research that measures how educational technology and student achievement are related is highlighted in the academic literature (King et al. 2016; Li & Ma, 2010; Lim et al., 2013; Page, 2002). For all these reasons, it is crucial for administration to know if ALEKS is an effective strategy for increasing standardized test scores. The results of this study will bring some clarity to this problem, which will also be a resource for school/district administration to refer to during the decision making process for new educational technologies.

Theoretical Framework

This study intends to bring some clarity to the nature of the relationship between a mathematics software used and student achievement because the unknown nature of this relationship is problematic for educators who implement this software to improve student learning. The software studied in this research is ALEKS, a web-based mathematics software that is founded on Knowledge Space Theory. When students first log in they take an initial assessment called the Initial Knowledge Check, an adaptive test in which each successive question is selected based on the students' responses to the previous questions.

At the end of the test, students' knowledge states are determined. Knowledge state refers to what students know and what they are ready to learn. Knowledge state is also known as students' knowledge map, as all maps show the current location, the destination, and what the next step is towards the destination. Students can choose from a list of topics determined by the program using artificial intelligence that they are ready to learn. Every time students learn 20-25 topics, the system gives them another test on the topics that they have recently learned. The questions are all open ended, and students use interactive tools on the screen to enter their responses.

The author of this study has been closely involved in the school-wide implementation of ALEKS for more than four years as a math teacher and assistant principal. When it was first adopted by the district, the administrative team strongly believed that it would make a difference in mathematics classes. The general intent was to boost historically low math test scores at the middle school level. Since ALEKS has a strong theoretical foundation (Knowledge Spaces Theory) it was naturally assumed that ALEKS might positively affect student learning. Partly because of this reason, no evaluation of ALEKS has been conducted since its adoption in this district.

This study mainly involves four aspects of education: mathematics curriculum and instruction, student achievement, effective educational technology, and educational leadership. Based on administrative decisions, a certain type of educational technology is adopted and implemented school wide or district wide with the purpose of improving student achievement by increasing the effectiveness of the instruction. These four aspects are closely related and define the theoretical framework of this study. At the study site school, the adoption of ALEKS was decided by the district but school administration determined the procedures for implementation. The goal in adopting ALEKS was to improve state test scores, one of the most widely accepted measurements of student achievement (Au, 2016), by increasing the effectiveness of the math instruction in schools.

Mathematics Curriculum and Instruction

Teaching of mathematics in the United States has gone through several stages since colonial times. The literature in this field shows significant changes between what it is now and what it was in past decades. According to Bidwell and Clason (1970), the rule method was the main way to deliver mathematics instruction during colonial times. In this method the students practiced following patterns and rules through several examples until they learned how to follow those rules. The deeper understanding of concepts was not necessarily a priority as long as one was able to follow the rules to solve a mathematics problem. This practice was first challenged by Warren Colburn's *First Lessons in Arithmetic on the Plan of Pestalozzi, with Some Improvements*, published in 1821 (Bidwell & Clason, 1970). Colburn emphasized the understanding of the operations and the use of manipulatives before introducing more abstract concepts. William Slocomb, Charles Davies, and Edward Brooks are some of the authors who contributed to the literature on the teaching of mathematics between the years of 1828 and 1890.

In the 1890s and the beginning of the 1900s, national educational organizations emerged and began to play a significant role in shaping mathematics instruction in the U.S. (Bidwell & Clason, 1970). Organizations such as the National Education Association, the American Mathematical Society, the College Entrance Examination Board, the Mathematical Association of America, the National Council of Teachers of Mathematics and others gave direction to mathematics education through comprehensive studies, reports, recommendations, standardization documents, and other efforts. The foundations for the junior high school program were laid out during this period and shaped by these organizations (Bidwell & Clason, 1970).

The report that was published by National Committee on Mathematical Requirements in 1923, called *The Reorganization of Mathematics in Secondary Education* or briefly the *1923 Report,* is one of the most influential documents in the history of mathematics instruction in the U.S. Bidwell and Clason (1970) argued that "the solidification of the junior high school-senior high school curriculum" occurred as a result of this report, and its influence "continued until the report in 1959 of the Commission on Mathematics of the College Entrance Examination Board" (p. 361). The report that was published in 1959 reorganized the secondary mathematics, which had significant impacts on teacher training (p. 533).

The reports in the 1980s such as *An Agenda for Action* (1980) and *A Nation at Risk* (1983) paved the way for the adoption of National Council of Teachers of Mathematics (NCTM)'s Curriculum and Evaluation Standards for School Mathematics (Klein, 2003). NCTM standards placed a strong emphasis on student-centered learning and progressive education. The use of manipulatives, calculators, and other technological tools were strongly advocated for in this document. Most states adopted NCTM Standards by 1997 after several years of aggressive promotion (Klein, 2003).

The *No Child Left Behind Act* (2002) had the most significant impact on K-12 education in the U.S. The legislation's main goal was to close the achievement gap among different groups of students in reading and math by 2014. The requirements of this act put pressure on districts and schools to find alternative tools to make instruction more effective in classrooms. Under this pressure, school leaders turned to technology, which led to a rapid increase in the use of educational technology in schools. Various devices and software programs were designed and experimented with to increase student achievement. Even though the studies regarding the effects of educational technology on student achievement show mixed results, educational technology has become an inseparable part of the modern classroom with an emphasis on improving learning.

Student Achievement

According to Sergiovanni and Starrat (2007), "what is assessed becomes or defines the curriculum" (p. 127), and state tests are significant to instruction. Schools are held responsible for the results of the state tests. When the results of the assessment show that the students are not learning, schools often devise alternative ways to make sure that students are learning. Sergiovanni and Starrat considered these efforts curriculum as well. To come up with effective alternative ways, the barriers to learning should be identified effectively. Some of these barriers might be teacher preparation, lack of necessary resources, teacher turnover, student motivation, and other variables (Boyd et al., 2009; Chudgar et al., 2015; Meece et al., 2006; Ronfield et al., 2013).

Standardized testing is often mentioned as a tool to assess racial equality within the context of accountability (Au, 2016). The results of standardized assessments reveal significant achievement gaps between different racial and socioeconomic student groups (Mendoza-Denton, 2014). For example, according to 2011 National Assessment of Educational Progress (NAEP) results, White students scored 31 points higher than Black students in eighth grade mathematics (Bohrnstedt et al., 2015). Although the phrase achievement gap is commonly used to describe the differences in standardized test scores between Black, Latinx, recent immigrant students, and White students, it also refers to disparities in dropout rates, higher level course placements and college graduation rates, and other factors related to schooling (Bohrnstedt et al., 2015; Chudgar et al., 2015; Ladson-Billings, 2006).

Standardized testing is frequently criticized and challenged by scholars. Au (2016) argued that standardized tests do the opposite of achieving racial equality and leads "to further racial inequality in education" (p. 39). Despite the "fact that testing policies…have had unintended negative consequences for the quality of American schooling," standardized test results are still often the focus when making decisions to reform schools (Darling-Hammond, 1991). According to Ladson-Billing (2006), it is not likely that focusing on achievement gaps that are mainly based on standardized tests will bring long-term solutions. Appel and Kronberger (2012) reported that stereotype threat is a phenomenon that negatively affects testing performance of certain group of students, and "a stronger focus on stereotype threat prior to test taking in research and practice can contribute to better achievement of those who are known to underachieve" (p. 630). In an experiment conducted with 32 Black and 44 White students, the participants completed a warm-up and a test under threatening and nonthreatening conditions; Black students' performance dropped by 60% under threatening conditions (Taylor & Walton, 2011). Threatening and non-threatening conditions in this study were considered as the task being evaluative in nature such as test versus warm-up, and the task being described to participants in a way that would trigger negative stereotypes about African Americans, such as "this study investigates how people from different backgrounds learn" versus "this study investigates psychological factors that contribute to different learning styles" (p. 1058).

Despite all the criticisms, standardized testing continues to be one of the most used and referred to measures of student achievement. Significant differences in standardized test scores are observed between groups of students. District and school administrations are expected and pressured to mitigate and eventually eliminate these differences. Such pressure leads school administrations to turn to technology as one of the strategies by which they can meet expectations.

Educational Technology

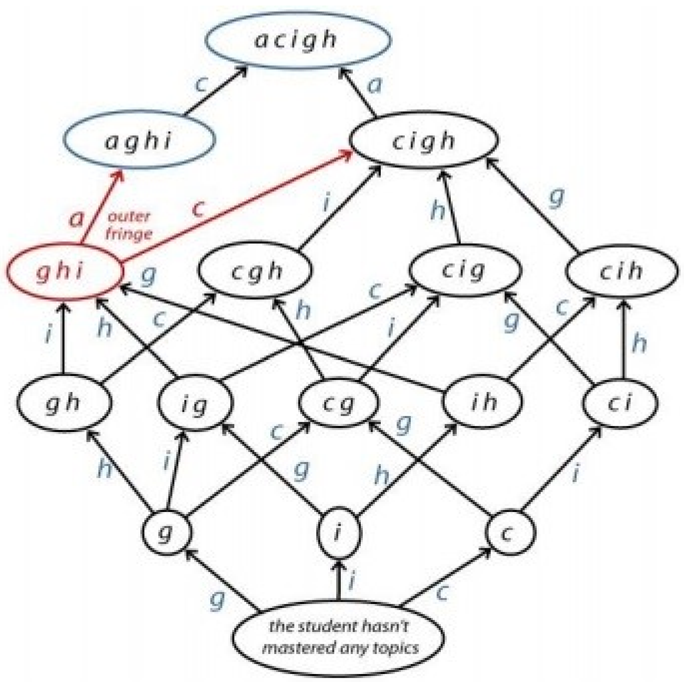
Since the focus of this study is a specific mathematics software, it can be viewed within the context of educational technology. In a meta-analysis study, Cheung and Slavin (2013) analyzed 74 research studies—45 elementary and 29 secondary—that investigated the relationship between educational technology and the learning of mathematics. Their findings showed that, compared to traditional methods, educational technology had modest, positive effects on learning mathematics.

Educational technology studied in this research is ALEKS, an artificially intelligent software founded on Knowledge Space Theory (KST), a theory that is further explored in the literature review (de Chiusole et al., 2015). Instead of assigning a numerical score to describe student knowledge after the assessment, ALEKS identifies the knowledge state of students in terms of what they know and what they do not know. Knowledge state is defined as "a particular set of problems that some individual is capable of solving correctly" (Doignon et al., 1990, p. 201). After identifying the knowledge states of students, ALEKS presents students a set of topics that they are ready to learn. According to KST, for any given subject, such as mathematics, all of the possible knowledge states are organized in a mathematical structure in which some of these states precede the others. The combination of all these knowledge states is called a learning space. Figure 1.1 shows a learning space of five topics: a, c, g, h, and i. The learner starts from the bottom of the figure and moves to the top as learning occurs. The red ellipse shows the current knowledge state, and the arrows direct to the topics that the student is ready to learn. A structure like this is created for a subject with 300-400 topics, which means more than a trillion possible knowledge spaces are available (ALEKS Corporation, 2012b).

A software program such as ALEKS that is based on a well-established theory, such as KST, tends to be more attractive to school leaders when it comes to deciding which technology to implement in order to close the achievement gaps. Selecting and implementing a certain technology school wide can be expensive and time consuming. For this reason, it is one of the main responsibilities of school leadership to select effective tools for instruction. Public funds can be wasted and effective instruction can be at stake if wrong decisions are made in this area.

Figure 1.1

Knowledge Spaces



As mentioned above, school leaders are responsible for the quality of the instruction, student achievement, and the selection and effective implementation of the educational technology in their buildings. They play a crucial role in bringing these three aspects of education together. For this reason, educational leadership is selected as the fourth topic of the theoretical framework of this study and is discussed in the next section.

Educational Leadership

In his article, “Change Theory: A Force for School Improvement,” Fullan (2006) claimed that “change theory or change knowledge can be powerful in informing education reform strategies and, in turn, getting results—but only in the hands (and minds, and hearts) of people who have a deep knowledge of the dynamics of how the factors in question operate to get particular results" (p. 3). Student achievement can be identified as the "results" in Fullan's statement which helps to construct the link between educational leadership and student achievement.

School leaders are expected to show short-term results along with long-term results. Fullan (2004) stated that "there is no excuse for failing to design and implement strategies that get short-term results" (p. 25). One of the district's goals in adopting ALEKS as a part of mathematics curriculum was to respond to the low test scores. In a meta-analysis study of 27 reports that involved district leadership and student academic achievement between 1970 and 2005 in the United States, Marzano and Waters (2009) studied 2,714 districts. They found a statistically significant correlation of 0.24 between district leadership and student achievement (p. 4). In a similar study that was conducted earlier at the school level, 69 studies involving 2,802 schools, 1.4 million students, and 14,000 teachers surveyed, and a correlation of 0.25 was found between school leadership and student achievement (Waters et al., 2005). With ALEKS it is possible for administration to monitor each and every individual's progress in mathematics closely. The software also gives concrete numerical data about student progress that can be easily processed and communicated with teachers, students, and parents.

Courville (2011) stated that "technology leadership is often viewed within the theoretical framework of change leadership" (p. 5). Fullan (2001) considered change as one of the six aspects of a framework he proposed for leadership. Schrum and Levin (2015) studied the award-winning leaders in several states who improved their schools and found a common trait was making deliberate and calculated attempts to change school culture through creating environments for teachers to take risks safely as they learn how to use new technologies in their classrooms. Considering technology is one of the fastest changing fields, one can recognize its impact on current leadership practices. Lambert (2002) considered “developing information and technology systems that support administrative and accountability functions, but are designed primarily to facilitate instruction, communication, and decision making” (p. 196) as one of the guiding principles for constructivist district leadership.

Often school leaders spend money on technology without a sufficient theoretical framework on how to use it. Sometimes this is only due to the pressure to keep up with the competing schools (Kolb, 2019). This type of pressure may lead to significant loss of financial resources. One of the most important responsibilities of the school leader is to ensure that these resources are not wasted as they are not unlimited. This study was designed with this intent in mind.

Design and Methods Overview

As previously pointed out, this quasi-experimental correlational study examined the relationship between students’ progress on ALEKS and their performance on middle school mathematics state tests. According to Gravetter and Wallnau (2012), most research can be classified in one of three basic categories: (1) A single group of participants with one score per participant; (2) a single group of participants with two (or more) variables measured for each participant; and (3) two (or more) groups of scores with each score a measurement of the same variable. This study analyzed the archived data of middle school students’ (a single group of participants) mathematical progress using ALEKS and state test scores (two variables). By definition, this study falls under the second category.

A Pearson correlation was calculated to find how these two variables were related because both of the variables were on an interval scale. Students' progress using ALEKS was the independent variable, and their performance difference on two mathematics state tests, before and after ALEKS, were the dependent variable. The state test that was taken prior to the use of ALEKS was considered a pre-test and the one after the use of ALEKS was considered a post-test. ALEKS itself was considered as a treatment between pre-and post-tests. Students' progress using ALEKS as an independent variable was measured by finding the percentage difference of students' topic mastery between the last and initial knowledge checks. The dependent variable, difference in state test performance, was measured by finding the change between the previous year and current year test scores.

The school that was studied is a sixth through twelfth grade school that serves 300 students in an urban charter school district located in the Midwest. The demographics of the school is 55% African American, 35% Latinx, and 10% White and other. All students at this school are enrolled in the Free and Reduced Lunch Program. The district adopted ALEKS in the 2014-2015 school year and has been implementing it since then; all students, except seniors, are required to use ALEKS.

The focus of this study was middle school students. The target population included urban middle school students in sixth, seventh, and eighth grade who were enrolled in a below Algebra 1 level math course. Archived data for ALEKS progress and mathematics state test results were analyzed. All middle school students who were attending this school and taking a mathematics course were the accessible population. Data were filtered to eliminate students who did not use ALEKS for a full year as well as those who did not take the state test prior to and/or after the use of ALEKS for that year; thus, the remaining students were the sample of this study. District and school administration were contacted to gain access to archived data for both ALEKS progress and state test scores.

Mean and standard deviation of the data were calculated as part of the preliminary analysis. A Pearson correlation and simple regression analysis were the suggested methods to analyze this data. Statistical significance in this case means that the student's ALEKS progress predicts improvement on a state test score to a certain degree.

Limitations, Validity and Reliability, and Ethical Considerations

The main weakness of quasi-experimental studies in general is that they cannot find causality between dependent and independent variables. To find a direct effect between the use of ALEKS and student test performance, a true experimental study would have to be conducted. However, it was not possible to conduct such a study due to the organization and operation of the school.

The researcher has implemented ALEKS in math classes as a teacher and supported district-wide implementation as an administrator when it was in the process of adoption. He has a positive experience with ALEKS, which would be the main bias of the researcher.

Limitations

Archived data analyzed in this study were from middle school students with low socioeconomic status (SES) at a small urban charter school which historically performed below the state average on state tests. One limitation of this study is that its findings may not be generalized to the groups of students who are significantly different from this group. For example, middle and high socio-economic status (SES) students who are attending a large public school with an above state average performance is significantly different. Also, the grade levels included in this study were sixth through eighth. However, ALEKS, the software that was evaluated, can be implemented at elementary and high school levels as well. Since the archived data used in this study is from middle school level, the results of this study may not be applicable for elementary and high school levels.

A third limitation would be that ALEKS is implemented in a specific way at this school. Mathematics classes are 90 minutes every day. The students spend every other mathematics period in computer labs working on ALEKS. The students who are struggling to reach their goals set by the school's administration are required to attend after-school or Saturday tutorials in which they have two to three hours to reach their goals. In that regard, the way ALEKS is implemented at this school may limit this study's results to this specific practice.

Since, this was a quasi-experimental study, it could not identify the direct effect of ALEKS on student performance in terms of causality. The correlation that was calculated could only give an idea regarding the nature of the relationship between ALEKS and student performance. This relationship may not be generalized to other educational technology in the market that are similar to ALEKS, as well.

Validity and Reliability

The instruments used to measure the correlation between ALEKS progress and student performance are the state tests that the students took before and after the implementation of ALEKS. Validity and reliability of this instrument is already established by the department of education of this state. Validity of an instrument is defined as how well the instrument measures what it is supposed to measure. Reliability of the instrument is defined as how well the instrument will repeat the results if used multiple times. Every year, the state publishes a technical report which provides comprehensive and thorough information about the validity and reliability of the test that is administered each year, including statistical analysis. According to this report, the mathematics tests were developed by Data Recognition Corporation (DRC). Test items were selected from DRC's college- and career-ready item pool. The assessments are aligned with state learning standards:

> Evidence of construct-related validity—supporting the intended interpretation of test scores and their use—was provided through studies of test reliability, evaluation of internal test structure, and evaluation of the relationship of test scores with external variables. The reliability analysis results indicated that the MAP tests produce scores that would be relatively stable if the tests were administered repeatedly under similar conditions. (Missouri Department of Elementary and Secondary Education, 2019, p. 4)

Validity and reliability of ALEKS program has also been measured by the founders of the program and a mean correlation of .67 has been reported between predicted and observed responses (Falmagne, et al. 2007; Yilmaz & Caruthers, 2017).

Ethical Considerations

The main ethical consideration of this study is that, the researcher used to be an administrator at the school to be studied who currently serves at district level. Due to the design of the study, no students were directly or indirectly contacted or communicated with. Since no human subjects were involved, this study qualified for Exempt IRB Review. The researcher successfully completed the Collaborative Institutional Training Initiative (CITI) program, which is an online training program to educate researchers about the issues that involve human subject research.

Lack of human subjects removes many ethical issues that may emerge in case of contact. However, as a former school administrator, the researcher used to have direct access to the student data that were used for analyses. This may raise other ethical concerns that need to be addressed such as the researcher's power as a current district level employee regarding student data. Powell et al. (2012) stated that power is a major issue “in considering the links between methodology and ethics” (p. 3). To protect the privacy of student data under the Family Educational Rights and Privacy Act (FERPA), necessary permissions were acquired from the principal and superintendent. The researcher worked with the school principal to make sure all personal identifiable information was removed before the data were provided. Data were saved in a password-protected laptop which was accessed only by the researcher. To be in compliance with the university’s ethical review protocol, data were collected and analyzed after the Institutional Review Board (IRB) approval was received.

Conclusion

This study explored the effectiveness of a specific educational technology that is being used as a part of mathematics curriculum and instruction in public schools based on the decisions of the school leaders. Therefore, this technology, ALEKS, was examined within the context of two main disciplines in the field of education such as educational leadership, and curriculum, and instruction. Such an interdisciplinary approach creates a deeper understanding of the problem of this study and demonstrates that the effective use of educational technology in public schools being the research topic of a single discipline may not be sufficient. Examining educational technology within the context of multiple disciplines may expand our understanding further and shed light to future research areas.

Chapter 1 provided a comprehensive view of this quasi-experimental, correlational study focusing on the contextual background of the problem statement and purpose of the study, its significance, research questions, summary of the theoretical framework, and overview of the methodology. The academic literature related to the study is reviewed extensively in Chapter 2 and expands on the topics that were discussed under theoretical framework. The literature review consists of four sections: (1) mathematics instruction, (2) student achievement, (3) educational technology, and (4) educational leadership. The design and methodology of the study, its limitations, validity and reliability of the variables and ethical considerations are discussed in detail in Chapter 3.

CHAPTER 2

LITERATURE REVIEW

This chapter presents a review of the literature that relates to the conceptual framework of the topic as outlined in Chapter 1. ALEKS, a research-based mathematics software program, has been adopted and implemented to improve test scores in many K-12 public schools in the last couple of decades. However, the support for the assumption that its use will improve student achievement is not clearly established in academic literature. The adoption of ALEKS without such evidence pushes school leaders to rely on articles and testimonials that have been published by the company itself. The purpose of this study is to analyze the connection between ALEKS's use and student achievement in mathematics. Bringing clarity to the nature of this relationship will create a reliable guidance for school leaders when deciding to adopt ALEKS in their schools.

Various academic databases such as Academic Search Complete, EBSCO, JSTOR, and Google Scholars were used to search for the studies related to the use of ALEKS in mathematics classes. The initial search revealed only five studies that are published in peer reviewed journals, four of which were conducted at the college level (Canfield, 2001; Hagerty & Smith, 2005; Smith, 2013; Stillson & Alsup, 2003; Stillson & Nag, 2009). Also, the results of these studies are mixed, which adds another layer of difficulty for school leaders who want make research-based decisions regarding its use in their schools. Hence, there is a need for more independently conducted studies on the effects of ALEKS on mathematics achievement, which will create a body of literature for school leaders to review before spending money, time, and effort on its adoption and implementation.

Relevant literature is discussed in this review for a thorough understanding of the context of this research as well as to demonstrate its significance. The topics are organized under four major aspects of education significant to this topic: mathematics instruction, student achievement, educational technology, and educational leadership. The literature in each of these broad topics is necessary to establish context through relevant empirical studies as well as theoretical and conceptual underpinnings for this study. The historical evolution of mathematics instruction in the United States is discussed along with the major changes and reforms and their effects on the current landscape of schooling. Knowing and understanding the effects of the major events, dominant philosophies, and policy changes on mathematics instruction in the history of the U.S. schools will provide a context to better understand the ways these have affected student achievement. Certain educational policy reports are discussed that have had great influence on public opinion, as well as opinions of government officials, leading them to demand higher expectations of school performance and student achievement (Klein, 2003; Lehnen, 1992).

Secondly, the measures and trends of student achievement are examined to provide guidance in identifying differences among student groups. These differences in performance and achievement are commonly referred to as the achievement gap and are well documented in educational literature (Bohrnstedt et al. 2015; Goldsmith, 2004; Hung et al., 2020; Ladson-Billings, 2006). Thorough discussion of student achievement in mathematics will help to explain why school leaders may be willing to utilize educational technology and how the technology may help to resolve issues with student achievement.

This chapter also briefly explores the history of technology and artificial intelligence in education and reports on research studies related to ALEKS, specifically. According to

Ferraro (2018), the effects of technology on student achievement has long been the center of discussions among educators. The literature in this area is analyzed and discussed to identify if technological tools, including ALEKS, have been able to deliver what was expected regarding mathematics achievement in the last several decades (Kirschner & Erkens, 2006; Spector, 2020).

Finally, the roles and responsibilities of educational leaders and their decision making processes regarding the implementation of technology are examined. The literature in this field suggests certain leadership characteristics required for a technology initiative to be effective (Anderson & Dexter, 2005; Thomas & Knezek, 1991). The relationship between ALEKS's use and student achievement also depends on implementation approaches by school leadership. Reviewing academic literature in this area added another dimension to consider in the undertaking of this research.

The review of the literature in these areas revealed that, in general, there is a need for the further examination of the relationship between technology and student achievement. This gap becomes more visible when the question is raised about a specific technological tool such as ALEKS. For this reason, the significance of this study is that it does not only contribute to the academic literature related to ALEKS, but also to technology embedded in the larger landscape of schooling in the United States.

In the following section of this chapter, the history of mathematics instruction in the U.S. is presented. This discussion will provide information about how teaching and learning of mathematics shifted throughout the decades and in what ways current mathematics instruction models were influenced by these changes. The intent is to view ALEKS within a historical context as an instructional tool in mathematics learning.

Curriculum and Instruction: Mathematics Education

The seminal work of Bidwell and Clason (1970) with the publication of *Readings in the History of Mathematics Education* is among a number of major resources that provided a thorough look into the history of mathematics education in the United States from 1828 to 1959. In this book, the authors collected major committee and commission reports as well as other documents that affected the evolution of mathematics education in K-12 public schools. These documents are grouped under four periods: 1828-1890, 1891-1919, 1920-1937 and 1938-1959. First, major historical documents, practices, and trends during these periods are discussed using the periods identified by Bidwell and Clason (1970). Other resources are used to gain various perspectives on the topic (Klein, 2003; Willoughby, 1967). The direction of the mathematics instruction between 1959 and 1980 and from 1980s until the recent years are examined to better understand current trends within a historical context.

The Colonial Period: 1828-1890

Formal education was not as accessible to everyone during colonial years as today. As the foundations of the modern public education were being laid during this era, the access for certain socioeconomically disadvantaged populations, Native Americans, African Americans, and women were actively being denied to this education. According to Anderson (1988), teaching enslaved children was considered a crime in some states from 1800 until 1835; however, some form of education was developed for African American children starting in 1860 with the attempts and efforts of ex-slaves. Despite these efforts, many African-American students had a limited opportunity to develop and apply their knowledge of literature, philosophy, politics, mathematics, science and languages "because of having to function in the lower spheres of the social order" (Woodson, 1990, p. 10).

Spring (1997) argued that even after public education was becoming more accessible for oppressed groups as time passed, it was predominantly used as a tool to teach these students Anglo-American culture as a superior culture to their own. Educational methods that were being used attempted to destroy the culture of these groups and replace it with the dominant culture. In the U.S., Native Americans have been a major target of such cultural genocide and deculturalization attempts through public education (Spring, 1997).

Girls' access to education was also extremely limited during this era. Madigan (2009) reported that girls were not allowed to attend town schools until the 19th century and when they were, only a small percentage did compared to boys. These schools prepared women only for certain professions such as nursing and teaching (Madigan, 2009). However, even with this limited access to education, the teacher preparation programs were not sufficiently educating women to stay in the profession throughout their careers, thus making the profession unstable with extremely high turnover rates (Hansot & Tyack, 1982).

Although public education was mainly accessible for White male students with higher socioeconomic status during this period, the quality of their education was not high. Hansot and Tyack (1982) reported that most public schools were one-room buildings in rural areas with the teachers who were "young, poorly paid and rarely educated beyond the elementary subjects" (p. 17). Mathematics was not a priority in the schools, and the focus was on reading and religious studies. The attitude towards mathematics in secondary schools started to change slightly after Harvard made arithmetic skills one of the college entrance requirements in the mid-eighteenth century (Willoughby, 1967). The need for arithmetic skills started to grow. These skills were added to the curriculum, but there were not enough trained teachers to teach those skills. For this reason, students were taught to apply the rules to the problems of similar nature until they mastered them (Furr, 1996). Deep understanding of the concepts was not the expectation nor was it possible due to lack of necessary teacher training. As previously discussed in the theoretical framework section of Chapter 1, this was the primary way of teaching mathematics during colonial years, which is also commonly referred as the "rule method" (Bidwell & Clason, 1970). In this method, the teacher presents a math problem to the students and solves it using a certain rule. Students are expected to memorize the rule that the teacher used to solve the problem. Then the students are given a set of similar problems to practice which they would be able to solve using the rule that had been memorized. The skill is considered mastered when the students are able to apply the rule successfully to a new set of similar problems.

The "rule method" was first challenged by Warren Colburn's ideas, which were published in *First Lessons in Arithmetic on the Plan of Pestolazzi, with Some Improvements* in 1821. According to Bidwell and Clason (1970) Colburn's work "marked the beginning of widespread concern with pedagogy in arithmetic teaching" (p. 1). The authors also considered Colburn's book "the most popular arithmetic text ever published" (p. 13). Colburn recognized a mental-discipline theme and introduced the teaching of mathematics through the discovery approach. Unlike the "rule method." in which a certain rule is introduced and its application is taught through practice, with the discovery approach students use manipulatives and hands-on activities to discover and understand the rule as well as its application at a deeper level. Recognition of the mental-discipline theme, as well as its expansion and formalization, was one of the most important developments in this period.

Bidwell and Clason (1970) identified two more important developments that occurred in this period. One of these developments is that a structure started to emerge for arithmetic wherein the concepts were taught and learned in a more systematic and logical way than it was before. This can be considered as the emergence of the mathematics curriculum in the U.S. This development was also due to increasing engagement between mathematical and psychological theory. The third major development of this era was the widespread use of manipulatives such as cubes, beans, corn, buttons, and so forth.

In addition to Colburn (1821), Davies (1850) and Brooks (1880; 1883), two other educators had a significant impact on mathematics instruction during this period. Their work on philosophy, psychology, and methodology of mathematics instruction, despite being significantly different from modern structures, laid the groundwork for its future direction. Examining the relationship between faculty theory and mathematics instruction, they believed that "one initally learned mathematics from quantitative reality through the faculties of perception and intituion, then extended the knowledge through such faculties as reasoning and imagination" (Bidwell & Clason, 1970, p. 2). *The Logic and Utility of Mathematics with the Best Methods of Instruction Explained* (1850) by Davies is the first book on mathematics teaching methods and *Philosophy of Arithmetic* (1880) by Brooks is the first methodology book for elementary teachers in the U.S.

In the first half of the 19th century, Swiss pedagogue Johann Heinrich Pestalozzi's ideas had a significant influence on American educators such as Colburn. By the end of the 19th century, the ideas of a German educator, August Wilhelm Grube, began to play an important role in teaching of arithmetic in America. Using the pedagogical principles introduced by Pestalozzi, Grube developed a system to teach numbers and operations with them (Seeley & Grube, 1888).

With formal education not accessible to everyone—including the poor, Native Americans, enslaved Blacks, and newly freed slaves, women and girls—through the work of these esteemed men, mathematics instruction between 1828 and 1890 was mainly affected by the ideas and attempts of individual educators. This trend shifted after 1890 with the emergence of national committees and organizations in the field of education, more specifically, mathematics.

Development of Mathematics as a Field: 1891-1919

Important to the development of mathematics as a field were related professional organizations. The reports that were published by these organizations eventually made them a leading force that gave direction to mathematics instruction in public schools. The earliest committees consisted of public-school administrators and college professors. Teachers, mostly female, were not involved in preparation and publishing of early reports (Bidwell & Clason, 1970). According to Boyle (2004), the lack of women's involvement in educational decisions, despite being the largest population of the educational community, was the result of a male-dominated society's demands. The feminization of education in the U.S. occurred mainly in the second half of the 19th century, mainly because of improved opportunities for males in other fields than education and the lower cost of women teachers, as they were paid significantly less than men (Grumet, 1988).

A report published in 1892 by the National Education Association (NEA)'s Committee of Ten on Secondary School Studies is one of the first reports that had a significant impact on the course of mathematics curriculum and instruction. This report suggested including algebra and geometry in mathematics curriculum in secondary schools. The NEA's Committee on College Entrance Requirements published another report in 1899 which "marked the beginning of concerted efforts to stabilize the secondary school curriculum for college entrance" (Bidwell & Clason, 1970, p. 127). The College Entrance Examination Board (CEEB) was established shortly after the publication of this report (Wightman, 2003).

During this period, the use of mathematics as a mental discipline started to decrease. The pragmatist approach to mathematics instruction became more popular. The foundational belief of this approach was that students should only be taught the subjects that had direct practical value (Klein, 2003). The shift from a mental discipline approach to a pragmatist approach mainly occurred due to the theories of psychologist Edward L. Thorndike. The traditional mental discipline approach assumed that mathematics should be taught because the skills learned through mathematics can be transferred to other areas of life. Thorndike's theories challenged this approach and became the main ground for the progressivists of this era. William Heard Kilpatrick, who was opposed to the mental discipline approach, is considered to be one of the most important progressivist educator in the history of education in America (Klein, 2003).

Thorndike (1906) analyzed the relationship between student performance on college entrance exams given by CEEB and their success in different subjects in college. The researcher analyzed data for 130 students through their junior year. The author mainly focused on English, Latin, mathematics, and science. The findings of the study showed that college entrance exams were not the predictor of student success throughout college.

Thorndike (1906) stated that “of the students who were in the lower half of the group in the entrance examinations nearly forty per cent. are found in the upper half in the last three years of college” (p. 942). The findings of this study raised questions regarding the reliability of the entrance exams. Thorndike (1906) was concerned that it was possible that someone who did not pass the exams and was not admitted to the college could have performed significantly better than the most students who did.

Kilpatrick argued that mathematics instruction should be limited in secondary schools. He suggested that it should only be taught to a small number of interested students. His views published in *The Problem of Mathematics in Secondary Education* report by the Commission on the Reorganization of Secondary Education of NEA were perceived “as an attack against the field of mathematics itself” by mathematicians (Klein, 2003, p. 10). The report was criticized by the Mathematical Association of America (MAA) and “led to the founding of the National Council of Teachers of Mathematics (NCTM) in 1920” (Furr, 1996). One of the main criticisms was that the committee that prepared the report did not include any mathematicians.

Development of Mathematics Requirements: 1920-1937

As a reaction to Kilpatrick’s report, the National Committee on Mathematical Requirements was formed under MAA, which included a group of renown mathematicians of the time. The committee published the most significant document of this period entitled “The Reorganization of Mathematics in Secondary Education,” which is commonly referred to as the 1923 Report (Bidwell & Clason, 1970). The report touched on a variety of topics such as “survey of secondary school curricula,” “psychology of learning mathematics,” “training of mathematics teachers in other countries,” and others (Klein, 2003). Unlike

Kilpatrick's pragmatic approach, which attributed value to mathematics based on its practicality, the ideas presented in this report emphasized the intrinsic value of mathematics. According to Bidwell and Clason (1970), its influence continued for the next 30 years but Klein (2003) claims that Kilpatrick's report was more influential within the educational community than the 1923 Report.

Later in this period, progressivist ideas became more widespread in education. Mainly inspired from Kilpatrick's writings, the "Activity Movement" became popular around the nation, especially at the elementary level. According to Klein (2003) "some proponents of the Activity Movement did not even acknowledge that reading and learning the multiplication tables were legitimate activities" (p. 11). The movement undermined the importance of mathematics as a subject matter and focused on educating children based on their needs and interests. But the movement did not grow without resistance. The resistance was mostly at the high school level, because teachers specialized in teaching one subject.

The Push for More Mathematics Instruction: 1938-1959

Progressivist ideas continued to trend in the 1940s, but public resistance against these ideas grew as well. Enrollment in high school mathematics courses decreased. Mathematics became an unpopular subject among educators. Some reports that were published in the pre-war years "tried to reduce the unpopularity of mathematics" but the war did not allow their effects on educational community to be observed (Bidwell & Clason, 1970, p. 532).

The war did not help the situation with mathematics instruction. According to Klein (2003) "the army recruits knew so little math that the army itself had to provide training in the arithmetic needed for basic bookkeeping and gunnery" (p. 12). The response to this deficit was the Life Adjustment Movement, which gained popularity during post-war years. However, it viewed mathematics as a practical subject that would help students in their daily lives rather than an academic subject. Although this view gained support among educators, it encountered resistance not only from mathematicians and mathematics teachers but also from parents. The advances in science, technology, and engineering during this period clarified much of the debate about the importance of mathematics as an academic subject. As a result, the Life Adjustment Movement died, and progressive education lost its dominance in schools.

All of these factors led to significant changes in the direction of mathematics curricula, which started in the beginning of the 1950s and continued until the 1970s. Mathematicians and mathematics teachers became increasingly more involved in the decision making process regarding the K-12 curriculum. The New Math movement gained momentum in the absence of progressivist ideas. The first major attempt to contribute to this New Math movement came through the University of Illinois Committee on School Mathematics (UICSM) (Bidwell & Clason, 1970; Klein, 2003). According to Bidwell and Clason (1970), “it was the first major reform group to incorporate modern views into its experimental materials” (p. 532).

After the Soviet Union launched the first space satellite, the push for more intensive mathematics and science courses became stronger. In 1959, CEEB’s Commission on Mathematics published a report called *Program for College Preparatory Mathematics,* which played a significant role in establishing the importance of mathematics. As a result of this and other similar reports published in the late 1950s, advanced courses such as probability, statistics, and calculus started being offered at the high school levels.

Several empirical studies were conducted during this period regarding the attitudes, motivation, methods, curriculum, guidance, enrolment, teacher education, textbooks, gifted children and trends related to mathematics instruction, which significantly influenced future research in this area (Kinney & Tulock, 1957). In one of these studies, Poffenberger and Norton (1956) analyzed the factors that determined the attitudes of students towards mathematics. They surveyed and interviewed 16 college freshmen who enrolled in two mathematics courses during the summer semester at the University of California, Davis. The findings showed that parents' attitudes towards mathematics and their expectations of their children's performance were strong factors that affected students' attitudes towards mathematics. Teachers were also identified as a strong factor. According to the researchers, "there was no evidence to indicate that the peer group had much influence upon any individual except perhaps to reinforce attitudes developed from previous experiences" (Poffenberger & Norton, 1956, p. 115).

In another study, Corman (1957) studied whether different amounts and kinds of given information in mathematical problems affected students' ability to solve them. To measure this effect, 233 students from eight high schools in New York and New Jersey were tested using a set of match-task problems with no information, some information, and much information given to solve the problems. The participants' mental ability was also tested prior to the experiment through Otis Self-Administering Test of Mental Ability. The results of this study showed that the amount of information did not make much difference for the students who were considered less able. On the other hand, more given information for more able students increased their ability to successfully solve the problems.

The Open Education Movement: 1960-1979

The pendulum shifted too far too quickly towards the opposite direction from the progressivist ideas. The teachers were not sufficiently trained to keep up with the momentum of the New Math Movement. The concerns and criticisms regarding the New Math movement started rising in early 1960s. According to Klein (2003), "by the early 1970s New Math was dead," (p. 18), and progressivist ideas started to reemerge, which gave rise to the Open Education Movement.

The ideas that were driving the Open Education Movement were essentially the resurrection of progressivist ideas of prewar periods. Once again the idea of student-centered instruction, with students choosing which topics to learn and when to learn them, became popular and dominated instruction in schools. However, by the late 1970s, the resulting effects of this type of education were observed to be not favorable, especially for low-income students who did not have access to necessary resources. Since these students were not being taught the basic mathematics skills in schools, there was a need to learn outside of schools to keep up with the mathematics curriculum. However, their families were either not sufficiently educated to help their children at home or not able to pay for additional tutoring. Standardized test scores continued to drop during this period, which forced schools to return to traditional methods of instruction.

The Development of Mathematics Standards: 1980-1989

As awareness regarding the concerning state of mathematics and science education increased, so did attempts to address those concerns. One of these attempts was a report called *An Agenda for Action* that was developed and published by NCTM in 1980 under the leadership of Dr. Shirley A. Hill, who was also a professor at University of Missouri-Kansas

City at the time. The main focus of this report was the problem-solving skills in mathematics classes. The report suggested that not knowing the basic skills should not create obstacles for students to master problem solving skills, especially when those obstacles can be overcome with the help of technology such as calculators.

Another significant report, *A Nation at Risk,* was published in 1983 through the Department of Education. It raised concerns regarding various areas of education such as the increased amount of remedial mathematics courses, the lack of standardized assessments, the ineffectiveness of teacher training programs, teacher shortages, textbook adoption process, and so forth (Klein, 2002). The report also emphasized the issues with basic skills or lack thereof, which resonated with the public and received much more attention than NCTM's *An Agenda for Action.* Despite representing opposing views at the time, both reports played an important role in the direction of mathematics in the 1990s. The ongoing battle between the views supporting basic skills versus problem solving or conceptual understanding continued for more than a decade.

In 1989, NCTM published the *Curriculum and Evaluation Standards for School Mathematics,* which is usually referred as the *NCTM Standards*. Although NCTM was against the progressivist ideas when it was founded in 1920, it changed over decades and became a supporter of such ideas by the 1990s (Klein, 2003). *An Agenda for Action* was the major document that contributed to *NCTM Standards.* Once again, the progressivist ideas such as discovery learning and student-centered learning started gaining popularity despite the criticisms.

Math Wars: 1990-2000

By 1997, *NCTM Standards* became the norm for Mathematics courses in most states. However, this period is mainly known for constant "disagreement between those who wanted basic skills versus those who favored conceptual understanding of mathematics" (Klein, 2003, p. 46). This disagreement is commonly referred as math wars, where parents and mathematicians were on one side supporting the emphasis on basic skills and criticizing *NCTM Standards,* the discovery model, and conceptual understanding, and educational administrators, professors of education were on the other side supporting the opposite. Parent organizations such as Honest and Open Logical Debate (HOLD) in California and New York, Mathematically Correct in California, Parents Raising Educational Standards in Schools (PRESS) in Wisconsin, and MathChoice in Texas were some of the most influential organizations to challenge the *NCTM Standards.*

California was in the center of math wars, where the biggest resistance against the *NCTM Standards* occurred. After ongoing conflicts for a decade, California adopted its own Math standards in 1997, which was a significant deviation from *NCTM Standards* and considered to be a win for the side that emphasized basic skills over conceptual understanding. However, the application of California standards in public school classrooms encountered its own resistance by school administrators, who were mostly supportive of *NCTM Standards.*

In 2000, NCTM published a revision titled *Principles and Standards for School Mathematics (PSSM).* Some of the extreme views were eliminated and basic skills were mentioned more in this document, but it was still similar to *NCTM Standards.* Although the tension between the sides slightly decreased, math wars continued to exist for another decade. Eventually, extreme views were abandoned, and common ground was found as discussed in the next section.

Closing the Achievement Gap in Mathematics: 2001 to Present

In 2006, NCTM released another report called *Curriculum Focal Points*. As a result of this document, the tension between the sides in math wars decreased. In this report, NCTM moved away from its radical views and made a step toward the resolution of a long-lasting conflict. Math wars eventually ended in 2008 with the help of the National Mathematics Advisory Panel appointed by George Bush.

One of the most significant documents in the history of the education in the United States, the No Child Left Behind Act (NCLB), was adopted in 2001. The act required states to create assessments to measure the learning standards not only in mathematics but also in reading and other selected subject and grade levels. The goal was to close the achievement gap in mathematics and reading by 2015. Technology used in mathematics education significantly increased during this period (Davidson et al., 2014; Lowther et al., 2008). To accomplish the goals that were set by NCLB, educators searched for alternative ways of instruction. NCTM has been encouraging the use of technology since 1989 but its suggestions were to a large extent limited to calculators (Klein, 2003). Over the past three decades there have been significant advances in technology, especially in artificial intelligence (AI). Several software programs were developed during this period, each of which claimed to close the achievement gap.

The next section discusses the measures of student achievement in the U.S. to establish a setting for further discussion of technology use in education. The evidence from nationwide studies is reported to analyze the causes of the differences, commonly referred as achievement gaps, between student groups. Finally, the role and potential of technology regarding the closing of the achievement gaps is examined.

Student Achievement in Mathematics

Student learning and achievement are at the center of all educational efforts within all levels of academics as well as the political hierarchy (Campbell et al., 2000; Hanushek & Rivkin, 2009; Lee, 2002). Measures of student achievement have become one of the most discussed topics in education in the last two decades (Etim et al., 2020; Lee & Reeves, 2012). But a nationwide structured attempt to assess student achievement in the United States started in 1969 with the National Assessment of Educational Progress (NAEP) "providing policy makers, educators, and the public with reports on the academic performance and progress of the nation's students" (Koenig & Edley, 2017, p. 1). NAEP's report is commonly referred to as *The Nation's Report Card* and is based on the assessments taken by sample student groups in different subject areas including mathematics.

NAEP's reports initially included only nationwide student performance on each test item. Over the years the reports evolved to include disaggregated data for grade level, race, ethnicity, gender, and other factors. Although reporting of state level data was prohibited in the beginning, this changed in the 1980s with increasing need and demand for cross-state comparisons. In 1990 NAEP started applying achievement levels to its assessments. These achievement levels were identified as Basic, Proficient, and Advanced, which continued to be used by several states in the post-NCLB era until the present day. The descriptions of the achievement levels were also released to inform policy makers, educators, and parents about the performance of the nation's students "in a variety of subjects such as mathematics, reading, and writing. The achievement level descriptors have changed and evolved as education in the U.S. went through the stages that were discussed in the previous sections.

As mentioned above, the broad use of achievement levels started with NCLB in 2001, when the states were mandated for the first time to create standardized assessments to measure student achievement annually. The act significantly increased the accountability of teachers, school leaders, and state officials regarding student achievement and pushed them to make changes to address the results of state assessments. Since state tests are administered to almost all students in the state with some exceptions, they provide individual student, teacher, and school level data. These data are essentially used to identify low performing schools and districts within the state, which puts pressure on such schools to find ways to improve student performance. On the other hand, the data are also used to identify high performing schools, which enables educators to make comparisons and analyze the circumstances and instructional strategies for higher level performance.

The analysis of state, national, and international standardized assessment results continue to be concerning, especially in the areas of mathematics and reading (Bohrnstedt et al. 2015; Rebarber, 2020). One of the major concerns these analyses have revealed in the last couple of decades is that students in the U.S. are performing lower than their peers in developed countries in these subject areas. For example, the Programme for International Student Achievement (PISA) assessed mathematical literacy of students in 34 countries in 2012. Brow (2018) pointed out the assessment measured the capacity of 15-year-old students “to formulate, employ, and interpret mathematics in a variety of contexts” (p. 727), and 26% of the students in the U.S. performed at a basic level. The results of the test ranked the U.S. 26th out of 34 participating countries, even though the U.S. has the highest student funding and above average educational level of parents when compared with the other countries. Considering that the performance rate in 2012 was the same as it was in 2003, after NCLB, the situation was particularly concerning.

Prior to NCLB in 2002, there was not enough information to measure the performance of public education statewide and nationwide. According to Lehnen (1992), "the demand for better indicators of school performance increased markedly in 1980s with the publication of *A Nation at Risk*" (p. 23). The Scholastic Aptitude Test (SAT) and American College Testing (ACT) data started being used to cross-compare states, since these two tests were the most administered nationwide assessments. In 1984, the Department of Education released the State Education Performance Chart for the first time in which SAT and ACT data for all 50 states and the District of Columbia were reported (Lehnen, 1992). However, either ACT or SAT is predominantly administered in each state, which does not make the cross-comparison of the states completely accurate (Ginsburg et al., 1988; Powell & Steelman, 1984). Additionally, SAT and ACT tests are mainly taken by college-bound students who are interested in scoring higher. This means that the average scores for districts, states, and the nation are not affected negatively as much as they would be if all students, including low-achieving students, took the tests. For that reason, the SAT and ACT scores may not depict a completely accurate picture of the situation from this perspective as well. Unfortunately, the results of these tests are still alarming, as the recent reports show that the students are not college ready, especially in mathematics (Adams, 2015). According to Arnold et al. (2012), college readiness "refers to the multidimensional set of skills, traits, habits, and knowledge that students need to enter college with the capacity to succeed once they are enrolled" (p. 2). The discrepancy between the achievement level of the students who graduate from high school and the expectations of colleges is a growing concern in education (Martinez et al., 2020). Donham (2014) reported that only a quarter of the students who took the ACT in 2011 were college-ready in reading and mathematics. Furthermore, according to one study that included more than 500 higher education institutions, certain skills such as reasoning, problem solving, and reading informational texts were identified as important as content knowledge for student success in college. High school graduates who attend post-secondary schools also are not well prepared in these skills (Conley et al., 2011).

The decline in average SAT scores was first recognized at the beginning of the 1970s and was attributed to the significant increase in the number of students who took the test (Beaton et al., 2011). The fact that more students were attempting to go to college was a positive shift in education. But even the average SAT scores of college-bound students were concerning; and by the late 1980s, this issue became one of the main discussion topics about the state of education. The policymakers recognized the average SAT scores were misleading because they did not include non-college-bound student data and thus showed the situation better than it was for the nation (Lehnen, 1992; Powell & Steelman, 1984).

Lee (2002) analyzed the Black-White and Hispanic-White achievement gaps in reading and mathematics since the 1970s using NAEP and SAT data and observed that the gaps narrowed by the 1990s. However, the progress that was made in the 1970s and 1980s slowed down later, and the gaps either stayed the same or widened by the 2000s. Lee's (2002) analysis of NAEP data showed during the period when these gaps narrowed the achievement levels for White students "was quite flat, whereas Black students made substantial academic gains" (p. 3). This trend changed in the early 1990s when the achievement level for White students started to improve at a higher rate than it did for Black students. One explanation for the shift in this trend is the change in focus of the learning standards and curriculum. During the period when minimum competency was the focus, learning low-performing students grew more than in high-performing students (Campbell et al., 2000; Lee, 2002; Loveless & Diperna, 2000). As the new and higher performing standards were adopted, the growth slowed down for low-performing students and increased for high-performing students.

Lee (2002) also reported three main factors that academic literature identifies to be the possible explanations for the achievement gap reduction in the 1970s. Changes in socioeconomic and family conditions, youth culture and behaviors, and schooling conditions and practices are the factors that could account for the gap getting narrower until the 1990s. However, his further analysis demonstrated that these same factors that are believed to explain the gap reduction do not explain the gap increase during the most recent decades. Lee (2002) gave several examples of how the indicators of these three factors are not related to achievement gap trends, one of which is expenditures per student in public schools. The increase in per-pupil expenditures was 60% between 1970 and 1986. This increase dropped to 17% from 1986 to 1997. Such a drop might explain the decrease in the academic performance of historically underserved students from 1986 to 1997, but it fails to explain the increase in White students' performance in the same decade.

Reardon (2013) analyzed data from 19 nationally representative studies to identify the nature of the relationship between socioeconomic status and achievement gap. Parent income and education level were used as two main measures of the students' socioeconomic status. Test score differences were used to measure the achievement gaps between groups. The author defined income achievement gap as "the average achievement difference between a child from a family at the 90th percentile of the family income distribution and a child from a family at the 10th percentile" and claimed that it "is now twice as large as the black-white achievement gap" (Reardon, 2013, p. 1). The Black-White gap was larger than the income gap fifty years ago.

The income achievement gap is "30 to 40 percent larger among children born in 2001 than those born twenty-five years earlier" (p. 1). Reardon (2013) offered four explanations that may have contributed to the increase in the income achievement gaps (p. 13):

1. Income inequality has grown during the last 40 years, meaning that the income difference between families at the 90th and 10th percentiles of the income distribution has grown.
2. Family investment patterns have changed differentially during the last half-century, so that high-income families now invest relatively more time and resources in their children's cognitive development than do lower-income families.
3. Income has grown more strongly correlated with other socioeconomic characteristics of families, meaning that high-income families increasingly have greater socioeconomic and social resources that may benefit their children.
4. Increasing income segregation has led to greater differentiation in school quality and schooling opportunities between the rich and the poor.

Nationally, as the administration of standardized tests expanded due to government policies, so did the accountability. The researchers started looking at not only the overall state of education but also disparities in achievement among different groups of students based on race, ethnicity, socioeconomic status, and gender. These differences in standardized test scores are commonly referred to as achievement gaps in the educational literature (Hung et al., 2020; Ladson-Billings, 2006). Mandated state tests taken by all students made the picture regarding the achievement gaps clearer, thus providing a more accurate report on the state of education across the nation in the last two decades.

According to Hung et al. (2020), “the literature on achievement gaps often compare these test scores across groups of students with differing attributes of interest, such as race” (p. 176). Several reports and studies show that certain groups of students achieve less than their peers in different groups (Bohrnstedt et al., 2015; Goldsmith, 2004). One report that is based on the NAEP assessment that was administered in 2011 shows that Black students scored 31 points lower than White students on eighth grade mathematics (Bohrnsdedt et al., 2015). The authors of this report also highlight that the academic achievement of these racial groups has increased when compared to the past decades. In another study based on NAEP assessment data, Vanneman and colleagues (2009) reported that “average mathematics scores were higher in 2007 than in 1990 for both Black and White eighth-graders” (p. 7). The gap was 31 points both in 2007 and 2011, which means that it stayed the same. In 1990, there was a 33-point gap between Black and White students. Even though the gap is slightly narrower in recent years, the difference when compared to 1990 was not identified as statistically significant. Similar achievement gaps also exist between Latinx and White students. According to Goldsmith (2004), Black and Latinx students are more likely to attend low performing schools. They also tend to learn less than Whites when they attend the same schools. The latest NAEP report that was released in 2019 shows that the gains students made in mathematics and reading since 2003 were statistically insignificant, and most of these gains happened in the first half of this period (Ferguson, 2020). The achievement gaps among student groups based on race, ethnicity, and socioeconomic status continue to exist (Hanushek et al., 2019). When compared to the NAEP results in 2017, only Latinx students showed progress in fourth grade mathematics. The scores declined for Native American students in eighth grade mathematics. No significant changes were observed in any other student groups in mathematics. Asian students outperformed all other groups in both grade levels in mathematics and reading. The scores declined in eighth grade reading for White, Black, Hispanic, Native American, and multiracial students. The report states, "in 2019, the White–Black score gap at grade 4 narrowed compared to 2000 and 1990; and at grade 8, the score gap narrowed in comparison to 2000" (NCES, 2019, para. 10). The White-Hispanic score gaps at both fourth- and eighth-grade levels in 2019 narrowed when compared to 2009 and 2000.

In a recent study, Hung et al. (2020) examined 2,868 school districts in the United States to identify the factors that contribute to achievement gaps in the areas of mathematics and reading. Their findings show that economic and racial inequality as well as the education level of the parents are the most statistically significant contributors. Interestingly, the study also found that student enrollment, student expenditures, and student-teacher ratios do not explain the achievement gaps between different racial groups.

One of the main contributing factors of student achievement is the teacher quality (Ballard & Bates, 2008). In a study that included 205,515 fourth grade students from 47 countries, the researchers found a significant relationship between teacher quality and student achievement (Blömeke et al., 2016). Teacher quality also contributes to the achievement gaps that exist between advantaged and disadvantaged students (Goldhaber et al., 2019). According to Goldhaber et al. (2019), “disadvantaged students tend to have less-qualified and less-effective teachers than their more-advantaged peers” (p. 14). Rivkin et al. (2005) analyzed data from 3,000 schools involving half a million students and found that teacher quality has a significant effect on student achievement. The researchers report that “one standard deviation increase in average teacher quality for a grade raises average student achievement in the grade by at least 0.11 standard deviations of the total test score distribution in mathematics and 0.095 standard deviation in reading” (Rivkin et al., 2005, p. 434). Teacher quality does not only affect test scores but also student attendance, discipline, and course grades (Jackson, 2018). Chetty et al. (2014) analyzed school district data and federal income tax records for 2.5 million students in grades 3-8 between the years of 1988 and 2011 and found that students who are exposed to higher quality teachers are “more likely to attend college, earn higher salaries, and are less likely to have children as teenagers” (p. 1). Disadvantaged students are more likely to have less qualified teachers than their advantaged counterparts, which is one of the leading factors of the student achievement gap. Such a difference in teacher qualification and effectiveness is also commonly referred to as the teacher quality gap among different student groups (Goldhaber et al., 2019).

In addition to the teacher quality gap, it has also been documented that the teachers hold lower expectations for the students of color (Diamond & Posey-Maddox, 2020; Ready & Wright, 2011). Cherng (2017) analyzed the data for 12,500 high school sophomores from a nationally administered survey and found that their mathematics and English teachers “are more likely to perceive that their class is too difficult for students of color compared to White students” (p. 180). In another study, the teachers were asked to rate the language and literacy skills of their first-grade students in 1,280 schools (Irizarry, 2015). After analyzing the data for 10,740 students, Irizarry (2015) found that “White, Asian and Latino students receive above average ratings with much greater frequency than do non-White Latino and Black students” (p. 534). Diamond and Posey-Maddox (2020) reported that more than 80% of the teachers in the U.S. are White and claimed that such a racial mismatch between students and teachers is one of the contributing factors for lower academic and behavioral expectations for certain racial groups.

Jones et al. (2018) reported that a strong link exists between the student achievement and racial and poverty composition of schools. African American and Latinx students who are more likely to come from low socioeconomic status households “became more racially segregated from whites in their schools from 1986-2000” (Orfield et al., 2002, p. 17). The segregation occurred despite the rapid increase in the number of students of color in schools during these years. Residential patterns, school choice, and court actions are some of the factors that contributed to the concentration of students of color in certain schools. Such segregation affects student achievement negatively as the schools struggle to compete for effective and high-quality teachers along with other resources that provide students access to math courses correlated with access to college (Byun et al., 2015; Long et al., 2012; Riegle-Crumb & Grodsky, 2010). Earlier efforts such as the Algebra Project (Silva et al., 1990) acknowledged that access to college and success depend on the exposure to gatekeeping courses such as algebra. The project was supported with a curriculum of high expectations for all students acquiring algebraic concepts and integrated students’ personal experiences with learning strategies to eradicate implicit bias toward marginalized groups of students.

Ladson-Billings (2006) provided a more complex explanation of the achievement gap conceptualized as an educational debt. She compared the achievement gap to the national deficit concept in economics which occurs when spending exceeds the income during one budget cycle. Similar to how the accumulation of annual deficits creates the national debt, the combination of achievement gaps creates the education debt, which has been accrued as a result of historical, economic, sociopolitical, and moral decisions and policies. Such an approach draws attention to the magnitude of the problem and allows it to be addressed within a larger context.

According to Oakes (1990), “the disparities for African-American and Hispanic minorities and the poor are so great that considerable science and mathematics talent is undoubtedly being lost from these groups” (p. 2). Higher performing students from these backgrounds have less access to high quality mathematics and science programs than their low-performing peers who are enrolled in more advantaged schools. Due to such disparities in access to resources, some researchers take the discussion on achievement gaps one step further, focusing on opportunity gaps instead. As Hung et al. (2020) described, “the education system actually presents an opportunity gap that leads to unequal outcomes, such as achievement gaps” (p. 177). This change in focus from achievement gaps to opportunity gaps is a shift from outcomes to inputs, where inputs are described as “the deficiencies in the foundational components of societies, schools, and communities that produce significant differences in educational—and ultimately socioeconomic—outcomes” (Ladson-Billings et al., 2013, p. 3). There is a growing concern among scholars regarding the negative impacts of the heavy focus on the achievement gap in academic literature. Gutiérrez (2008) referred to this phenomenon as gap gazing and claimed that a constant examination of the achievement gap distracts the attention from the problems that are embedded within the system. According to Gutiérrez and Dixon-Román (2011), “most researchers and practitioners fail to question the underlying assimilationist goal and the way in which framing the problem as an achievement gap supports deficit thinking and negative narratives" (p. 23).

Talbert-Johnson (2004) reported that the main cause of the achievement gap among different racial groups is poverty, and about 60% of all children who live in poverty in the U.S. are students of color. She claimed that the role of school and the education system in general also play a significant role on this issue. More specifically, students of color are more likely to not have a sense of belonging to the school or learning community, which is an indicator of low motivation and low interest for educational gains. Certain policies and practices such as discipline consequences where African American students are punished more severely compared to White students of the similar age and socioeconomic status, can be one of the reasons for the feeling of disengagement from school (Blyth & Milner, 1993; Cartledge et al., 2001; Reitzug, 1994). Talbert-Johnson (2004) suggested training teachers to be culturally responsive and increasing teacher quality in schools to address the issue of the achievement gap. The author also concluded that "culturally responsive teachers are able to modify pedagogy and curricula to address the specific learning needs of their students" (Talbert-Johnson, 2004, p. 33).

In an evaluative report, Flores (2007) claimed that by eighth grade more than 85% of African American and Latinx students are not proficient in mathematics, which is more than 25% higher than White and Asian students. She claimed that this achievement gap is due to the opportunity gap that certain groups experience in schools. One example of the opportunity gap is the access to high quality teachers. African American and Latinx students are not only more likely than White students to be taught by inexperienced teachers but also are less likely "to have teachers who emphasize high quality mathematics instruction, and appropriate use of resources" (Flores, 2007, p, 32). Ladson-Billings (2006) claimed that "the vast majority of underprepared entrants teach low-income and minority students in central cities and poor rural areas" (p. 12). Working conditions and salary are the main reasons that high-quality teachers are not willing to be employed in poor districts. The situation is much worse in the fields of mathematics and science.

Limited access to highly qualified teachers is not the only factor that contributes to the existence of an opportunity gap. One other contributing factor is lower expectations for African American and Latinx students usually due to the bias towards their socioeconomic status, household situation, and cultural background. According to Delpit (1992), teachers tend to believe these factors play a more significant role in student failure rather than admitting that their instruction may not have been effective enough. Such belief leads to teachers lowering their expectations and teaching less instead of identifying the weaknesses in their own instructional strategies and improving them (Delpit, 1992).

Fryer and Levitt (2004) analyzed the data from the Early Childhood Longitudinal Study kindergarten cohort (ECLS-K) with a sample of more than 20,000 students entering kindergarten in 1998 to gain a better understanding of the Black-White test score gap. The authors looked at math and reading standardized test scores which were administered orally at the beginning of kindergarten and at the end of the first grade. The tests measured basic skills, vocabulary and comprehension, knowledge of the alphabet, phonetics, number recognition, counting, comparing and ordering, solving word problems, and interpreting picture graphs. The findings of this study show that the Black-White gap in math in the beginning of kindergarten was 0.638 standard deviation, and it increased to 0.728 by the end of the first grade. The gap in reading increased similarly from 0.401 standard deviation to 0.529 for the same period. The authors explored several possible explanations such as quality of schools, parental and environmental contributions, summer setbacks due to home and neighborhood conditions, the validity and reliability of the tests, the relationship between Black students and schools that may interfere with their learning, and others. The researchers concluded that the most likely explanation for Black students losing ground relative to White students over the first two years of school is because they attend poorer schools compared to those of White students.

As discussed above, despite ongoing efforts at all levels of educational and political hierarchy, the achievement gaps between different groups of students continue to exist. The significant increase in the use of technology in K-12 setting is also part of the efforts in closing achievement gaps. As the educational technology becomes more sophisticated, it gives schools and teachers tools to differentiate the instruction in the classroom, enabling individualized and personalized learning experience for the students. However, the growing pace and variety of technological tools that are available in the market make the evaluation of their effectiveness on student learning difficult. Frequently, schools decide to implement certain technology based on limited information with little to no evidence about its effectiveness.

In the next section of this chapter the history of educational technology is explored, and its effectiveness on the student learning is analyzed. Further, the findings of the educational research on software programs that use artificial intelligence are reported and compared to ALEKS, which is predominantly used in mathematics classrooms both at high school and college levels. The goal is to establish the relationship between educational technology and student achievement.

Educational Technology

Information and Communication Technology (ICT) use in education has been on the rise since the late 1980s (Ross, 2020). According to Andronie and Andronie (2014), “research conducted in the United States shows a significant increase of the number of students that are studying by using technological support (in the form of e-Learning tools)” (p. 379). Ross (2020) claimed that the beginning of the rapid growth in the use of educational technology overlaps with the period when the demand for school and teacher accountability for student achievement increased. As mentioned above, with NCLB, accountability for student achievement became the emphasis in education. As federal and state policies started holding the schools accountable for student performance, school personnel explored the use of technological tools to comply with these policies. As a result, most schools started using educational technology to support instruction in the classroom, collect information on student, teacher and administrator performance, and communicate with the parents (Enomoto & Conley, 2007).

The effects of ICT on student achievement have been centered on discussions regarding technology’s role in education among educators and policymakers (Ferraro, 2008). The rapid growth and integration of technology in education have been both supported and criticized by the experts in the field (Kirschner & Erkens, 2006; Spector, 2020). One of the earliest attempts to integrate computers in the K-12 classrooms was initiated in 1986 by Apple Computer, Inc. (Ross, 2020). These classrooms were officially named Apple Classroom of Tomorrow (ACOT) and were specifically designed to study educational technology as a part of a nationwide initiative (Ross, 2020). ACOT was implemented in seven classrooms across the nation where every student and teacher were equipped with one computer for classroom use and one for home use, since portable computers were not available at the time. A study conducted in one of these classrooms with 100% high poverty African-American fifth grade students—70% of whom were considered low performing in mathematics and reading based on the state assessment results—revealed an increase in the state assessment scores compared to the previous year. Authors claim that although this was not a controlled study, their findings demonstrated a potential of technology to help low-performing students, increase engagement, and close the achievement gap (Ross et al., 1989).

Reeves and Oh (2017) identified six objectives of the research on technology in education:

- to develop theoretical knowledge
- to test conclusions of the theories and models
- to describe and interpret related phenomena
- to examine the assumptions and hidden agendas
- to create and improve effective solutions in practice, and
- to evaluate the effectiveness

The research on the effectiveness of technology also varies. Some studies are more general as they focus on overall effectiveness of using technological devices in education such as statewide or school-wide one-to-one technology initiatives. Others are focused on a specifically developed instructional software programs rather than devices. Based on this identification, this study falls under the first category as its objective is to get more information regarding the effects of ALEKS on mathematics skills of students. Ross (2020) suggested that a computer-based instruction (CBI) lesson that is designed sufficiently well "should produce higher achievement compared to one of lower quality presented by a teacher workbook" (p. 2).

With the significant advancements in computer technology and internet, some states led the process of technology integration in teaching and learning in K-12 education. Maine is one of those states that started to provide students and teachers with laptops under Maine Learning Technology Initiative (MLTI) in 2002. Silvernail and Lane (2004) studied the impact of the initial phase of Maine's one-to-one laptop program in which approximately 34,000 seventh and eighth grade students and over 3,000 teachers received laptops. The researchers conducted on-line surveys, paper surveys, site visits, interviews, classroom observations with teachers, students, principals, superintendents, technology coordinators and parents and analyzed documents such as policies and procedures, lesson plans, and student work, Approximately 26,000 students and 1,700 teachers were surveyed and data from 39 site visits were collected and analyzed in a 15-month period. The study mainly focused on how the use of laptops changed the nature of learning and the teaching process rather than academic achievement. The findings showed that more than 80% of the teachers reported that the students were more motivated, engaged more actively in their learning, and produced higher quality work. Using laptops helped teachers to meet curriculum goals and state standards and create more effective, individualized instruction for students.

The impact of MLTI on student achievement was studied later by Silvernail and Gritter (2007). The researchers compared data from 2000 and 2005 to identify if student achievement improved after the five-year implementation of a one-to-one laptop program.

The study showed that the average writing score of eighth graders on the state assessment increased by 3.44 points with an effect size of 0.32. Additionally, students who used laptops for writing extensively during the learning process scored significantly higher than the students who did not use laptops for writing.

In a more recent study of an MLTI program, the researchers reported that a "well-designed and executed professional development resulted in improved student performance in mathematics" (Silvernail et al., 2011, p. 1). The study also found significant improvement in short-term and long-term science achievement. The authors concluded the statewide one-to-one laptop program had been successful after eight years.

The Texas Technology Immersion Pilot (TIP), another statewide one-to-one laptop program initiated in 2004, showed similar results among 16,000 students in sixth, seventh and eighth grades and 1,253 teachers in mathematics. The program was evaluated by the Texas Center of Educational Research (2008) through the collection and analysis of data over a three-year period, 2004 to 2007. The students represented 42 rural, urban, and suburban schools across Texas, where half of the schools comprised the treatment group, and the other half of the schools were the control group. More than 60% of the students were predominantly students of color and poor. As noted, the initiative had a statistically significant effect on mathematics state test achievement but not on reading.

Statewide and district-wide initiatives such as the ones described above accelerated the adoption and increased the proficiency of technology use. As the hardware devices became better and faster, software programs also developed and became more sophisticated. Likewise, the evolution of educational technology has also been influenced by pedagogical changes. Handal and Herrington (2003) discussed various uses of computers in learning such as drills, tutorials, games, simulations, and hypertext, each of which is based on a different pedagogical approach. The pedagogical approaches behind these types of computer use are behaviorism, cognitivism, and constructivism. According to Ertmer and Newby (1993), "behaviorism equates learning with changes in either the form or frequency of observable performance" (p. 48). The behaviorist approach is considered a basis for drills and tutorial types of computer use. Games and simulations are based on cognitive learning models, in which learning is achieved through more complex cognitive processes such as critical thinking and problem solving (Nwagou, 2012). Constructivism suggests that learning occurs through deriving meaning through experience (Ertmer & Newby, 1993). Hypertext and hypermedia-based instruction allow students to take active roles in their learning and create their own personalized learning environment for themselves (Nwagou, 2012).

One specific technological achievement, artificial intelligence (AI), has had a significant impact on the development of educational software programs. AI has the capability to learn from the human inputs and interactions, thus supporting a personalized learning experience at the individual level. In the field of education, AI made it possible to build adaptive learning technologies and intelligent tutoring systems such as ALEKS.

Artificial intelligence structure used in ALEKS is based on Knowledge Space Theory (KST), which was developed in the 1980s by a mathematician and professor of cognitive sciences, Dr. Jean-Claude Falmagne (Yilmaz & Caruthers, 2017). According to KST, a group of concepts are considered prerequisites and need to be mastered before the other group of concepts are learned. There is a relation among the concepts within a certain subject, defined as precedence relation (Falmagne et al., 2006). This relation can be detected and mapped out more easily in mathematics.

According to Falmagne et al. (1990), the core concept of the theory is that "the *knowledge state* of a subject with regard to a specified field of information can be represented by a particular subset of questions or problems that the subject is capable of solving" (p. 201). Another essential concept is *knowledge space*, defined as the collection of all knowledge states. Knowledge space can be viewed as a structure that maps out the learner's all possible states of knowledge within the field. The theory is designed to provide a framework for an effective assessment of knowledge. Assessing student knowledge prior to further instruction is a strategy that teachers use in the classroom regularly. By doing so, teachers plan their lessons to address the individual needs of their students accordingly. Software programs that are based on KST are essentially designed to accomplish the same goal. In fact, the first step in building a knowledge space is done by querying the expert teachers (Koppen & Doignon, 1990). However, it is not realistic for experts to identify all knowledge states and build a knowledge space for any specific field. A knowledge space may consist of several hundred thousand knowledge states which is impossible for the human mind to process. The development of computer technology has made the practical implementation of the theory possible and easy. Computers are now capable of assessing "what the student can do" and "what the student is ready to learn" by analyzing as large amount of data as necessary to identify the exact knowledge state of an individual accurately (Falmagne et al., 2006).

ALEKS is the most popular implementation of KST and part of the mathematics curriculum not only in K-12 schools but also colleges around the nation. Despite this, the number of studies that have been conducted to evaluate the impact of ALEKS among K-12 students is limited; most of these studies were done at the college level. The studies also vary in terms of what they measure such as student perceptions and effects on achievement. Canfield (2001) was one of the earliest researchers who studied student perceptions of ALEKS usage at the college level through surveys. The study was conducted in National-Louis University, where 30 students took intermediate algebra and remedial arithmetic courses during the Summer and Fall 2000 terms. Survey results showed that student perception regarding ALEKS usage was overwhelmingly positive. Eighty percent of the students said “they learned as much or more mathematics with ALEKS, they would take another course which used ALEKS, and they would recommend the use of ALEKS to another student” (Canfield, 2001, p. 152). In conclusion, Canfield (2001) recommended ALEKS to be used as a supplemental tool for the main instruction rather than a stand-alone program. However, ALEKS might benefit self-motivated students as a main instructional tool. Demographic information was not reported in this study to analyze the implications of the results for diverse group of students.

Stillson and Alsup (2003) explored the effectiveness of ALEKS in three college level Basic Algebra courses. The courses were taught by the same instructor during the Fall semester in 2001. The study involved 59 participants out of 108 students who completed the course. Of the 59 students, 44 were female, 14 were male, and 41 were between the ages of 18 and 24. Disaggregated data by race were not reported. ALEKS work was mainly implemented as a tool to assign homework to the students. The researchers analyzed different types of data to study ALEKS from different perspectives such as student perceptions, impact on performance, and instructor observations. For the interviews, the researchers used questions similar to those from Canfield’s study that was mentioned above.

Most of the participants responded that they learned more with ALEKS (61%), would take another course using it (73%), and would recommend it to a fellow student (78%).

One major finding was that the students who scored higher on the five tests during the semester and received higher final grades in Basic Algebra also spent more time and mastered on the average a larger number of topics related to ALEKS (Stillson & Alsup, 2003). As the grades decreased, so did ALEKS engagement. However, when the number of failing students in Fall 2001 was compared to the previous three semesters, when the same course was taught by the same instructor without ALEKS, there was a noticeable difference. The failing percentages for Fall 1999, Spring 2000, and Fall 2000 semesters were 15.4%, 29.8%, and 19.6% respectively. In Fall 2001, when ALEKS was implemented for the first time, 42.6% of the students failed the course. The number of students who dropped the class was also considerably higher than the previous semesters. Disaggregated data based on gender and race were not reported. When the instructor was asked to share their observations during the interview, a concern was raised that there were students who did not even log on to ALEKS throughout the semester despite several reminders that ALEKS work was 25% of the final grade. The instructor assumed that learning how to use ALEKS on top of mathematics concepts was an additional difficulty for some students (Stillson & Alsup, 2003).

Another higher education study involved 251 students enrolled in eight sections of a college algebra course that were taught by four instructors during Fall 2003 (Hagerty & Smith, 2003). ALEKS was used in four of these sections as part of the instruction. The other four sections did not use ALEKS and were considered a control group. Students were not aware of ALEKS and non-ALEKS sections when they enrolled. Students in the control group were taught using traditional textbook. Pre- and post-tests were designed based on the traditional and established curriculum. Additionally, a survey was developed to gather data about students' mathematics backgrounds and their opinions of mathematics and computers.

Findings of the pre- and post-test data analysis showed that "the students using ALEKS outperformed the students comprising the control" group in three of the four ALEKS sections (Hagerty & Smith, 2005, p. 188). The researchers also conducted a regression analysis controlling for ACT mathematics scores taken in the last two years and found that 11% growth at the end of the semester was due to ALEKS use and did not depend on previous knowledge. However, this growth did not create a significant difference in Drop/Withdrawal/Failure rates between ALEKS and textbook-based classes, as these rates were 27.8% for the former and 25.5% for the latter, which is a 2.3% difference.

As reported, student surveys were also part of this study. According to the researchers, "the major outcome from this survey indicated that if the ALEKS curriculum was to be adopted, computer access and ALEKS-related tutorial help should be enhanced" (Hagerty & Smith, 2005, p. 191). Although one of the main concerns was the alignment of the ALEKS topics with the traditional textbook, the students felt positive about their overall ALEKS experience.

Smith (2013) described another implementation of ALEKS in two sections of a hybrid Basic Algebra course in 2010 that involved 80 students. The author suggested that because of ALEKS implementation, the passing rates increased by 27%. Additionally, "a 17% increase in student attendance and a 12% increase in retention rates" were also attributed to the first time ever ALEKS implementation.

At Louisiana Tech University, Carpenter and Hanna (2006) studied ALEKS that had been implemented for five years as a tutoring program for Calculus I students. The researchers intended to clarify if ALEKS was a better predictor of student success compared to ACT Mathematics scores, which historically had been used to place students in Calculus I. To enroll in Calculus I, students must have a minimum score of 26 on ACT Mathematics. A student with a score of 24 or 25 may also be eligible to take the course after completing a college algebra course as a prerequisite. The researchers compared ACT Mathematics scores and ALEKS initial assessments results with course grades where getting a C or higher grade on the course was defined as student success. To analyze data, ALEKS initial assessment percentages were grouped, and a Kruskal-Wallis nonparametric test was run on letter grade ranks. The results of this analysis showed that the students "with a higher initial ALEKS assessment score earned higher grades in the class" (Hanna & Carpenter, 2006, p. 7). Similar analysis revealed that ACT Mathematics did not predict student success as well as the initial ALEKS assessment.

Hampikian et al. (2006) studied the impact of ALEKS that was used in Pre-Calculus and Calculus I courses for engineering students. A total of 45 students who took these courses in Fall 2005 at Boise State University were involved in the study. To find if ALEKS was successful, the researchers performed Analysis of Variance (ANOVA) to measure the differences between mean grade and used Chi-square to measure the differences in proportion passing the course with a C or higher grade. Analysis for both courses showed that ALEKS had a positive impact on the grades, but it was not statistically significant due to the small sample sizes. The researchers also found that the more time the students spent on ALEKS on average, the higher their grades were. Hampikian et al. (2006) found no correlation between initial ALEKS assessment score and student success, which contradicted the findings of Carpenter and Hanna (2006) that the initial assessment was a better predictor of student success than ACT Mathematics score. A related study was conducted at the same university by Hampikian et al. (2007) to compare the performance of 37 engineering students who used ALEKS to that of those who did not. ALEKS students were expected to show 4-6% weekly progress with the goal of 65% or 75% mastery by the end of the Fall 2006 semester. The researchers found that the mean scores were higher for ALEKS students than for non-ALEKS students, but the findings were not statistically significant at the $p<.05$ level, possibly due to the small sample size.

Another undergraduate level study was conducted to explore the relationship between ALEKS and racial achievement gaps in behavioral statistics course (Hu et al., 2008). The researchers used a nonequivalent group design method to identify if there was a significant difference between the traditional instruction and ALEKS groups. In total, 183 African-American and 365 White students participated in the study. Of the 548 students involved, 411 were taught via the traditional way of instruction and 137 used ALEKS. All students were taught by the same instructor from 1995 to 2005. Student grades during this period were analyzed to identify if ALEKS use made a difference in closing the achievement gap between Black and White students. The researchers found that the Black students who used ALEKS had a significantly higher average grade than the ones who were enrolled in the traditional course format. Additionally, no gap was observed between the average grades of the Black and White students in the sections that used ALEKS. However, such racial disparities existed among student groups in lecture sections. The authors concluded that their "analyses demonstrate the potential value of an online ITS as a tool for eliminating racial disparities in college students' academic performance" (Hu et al., 2008, p. 9).

In one college level study, Taylor (2008) investigated the effects of ALEKS on student performance, mathematics anxiety, and attitudes towards mathematics. The students enrolled in the classes using ALEKS were compared to traditional lecture courses. A total of 93 students from five different higher institutions participated in the study. The participants were 69% White, 10% African American, 18% Hispanic, and 3% from other racial backgrounds. The increase in mean scores between pre-test and post-test results was found to be statistically significant with Cohen's d of 0.611, which suggested that ALEKS use improved mathematical achievement. The study also found that the mathematical anxiety of the experimental ALEKS group with 54 students decreased at a higher rate towards the end of the semester when compared with the control group with 39 students. Attitudes of the ALEKS students towards mathematics also improved but was not statistically significant, whereas the attitudes of the control group students were worse and statistically significant.

Xu et al. (2009), on the contrary, found no difference in student performance in a graduate-level introductory statistics course when they compared traditional and hybrid sections where ALEKS was used in the latter. A group of 45 students was taught in traditional face-to-face format in Fall 2005 and another group of 41 students was taught in hybrid format using ALEKS in Fall 2006. Both sections were taught by the same instructor. The researchers collected quantitative and qualitative data such as gender, age, race, course exam results, GRE scores, survey and interview data. Of the 86 participants, 66% were female and 34% were male. Age was not included as a direct indicator. Since the majority of the participants were either African American or White, the data were not analyzed for other racial groups. The analysis of quantitative data revealed that there was no significant difference in student performance between hybrid and traditional formats. Student performance was measured as the total exam score that the student received from two midterms and one final exam. There was a significant difference in the total exam score between African American and White students. However, the authors found that race did not make a statistical difference on student performance when compared to whether the students were in a traditional or hybrid classroom. Students' GRE score was the only factor and predictor of their performance in the class. According to the survey and interview data, students had major concerns regarding ALEKS being time consuming, not matching the textbook, and its assessments causing frustration.

Nwaogu (2012) investigated the effects of ALEKS on students' mathematics achievement in an online learning environment by analyzing the correlations between the various sets of data as indicated below:

- Weekly concept mastery and the achievement scores in weekly formative assessments (quizzes).
- Time spent learning in ALEKS per week and the achievement score in weekly formative assessments.
- Total time spent in ALEKS and final concept mastery.
- The final concept mastery score and the post-test scores.
- Total time spent in ALEKS and the post-test scores.

A Pearson correlation coefficient was calculated for all five cases. The data were collected from a college mathematics course with a total of 80 students. More than 42% of the participants were White, 20% were African American, 3.4% were Hispanic, 8.5% were

Asian, and 25% did not report their race. More than 70% of the students were female and 94% were above the age of 22. Unlike the other college level studies, ALEKS was used as the primary source of instruction in this study. The findings showed that there was a significant, linear, and positive relationship between weekly concept mastery and the achievement scores in weekly formative assessments. Time spent using ALEKS was not correlated with weekly quiz results, final concept mastery, and post-test scores. However, there was a strong positive correlation (.852) between the final concept mastery scores and post-test scores. This means that the "participants who scored high on concept mastery also scored high on the posttest" (Nwaogu, 2012, p. 78).

While many of the studies were conducted at the college level, LaVergne (2007) conducted an action research to find the impact of ALEKS on the Algebra I test scores at Shawnee Mission South High School, in Shawnee Mission, Kansas. A total of 98 students were involved in this study. Student demographics were not reported. Measures of Academic Progress (MAP) tests developed by Northwest Evaluation Association (NWEA) were used to assess the course mastery. MAP tests were administered in the fall and winter of the 2006-2007 school year. The students who were involved in this study used ALEKS between the two tests as an interactive tutor in addition to the regular district curriculum. LaVergne (2007) examined the improvement in the results of two tests and compared them to the district and national averages. The students who used ALEKS improved by 2.7 points, whereas district and national averages were 1.0 and 1.6 points respectively. The author of the study concluded that ALEKS had "a significant positive impact on students' standardized math test scores" (LaVergne, 2007, p. 7).

In one K-12 level study, researchers evaluated the effectiveness of an after-school program that used ALEKS as an intervention tool for mathematics (Craig et al., 2013). The study involved 253 sixth grade students who were randomly assigned to non-ALEKS and ALEKS classrooms. The after-school program continued for 25 weeks and mainly focused on the state test preparation. Non-ALEKS students were taught by teachers who were also experts on state tests. The researchers compared the two groups' fifth-grade state test results that the students had taken at the end of the previous year, prior to the program and found no significant difference between them. Similar analysis was done after the program with the sixth-grade state test scores and no difference was found between groups. The authors concluded that the students in the ALEKS group performed at the same level as the students who were assigned the teacher-led groups. Student engagement level for both groups was the same as well.

In another K-12 level study Yilmaz & Caruthers (2017) analyzed student performance on the MAP test. Student scores were compared between ALEKS and non-ALEKS users to identify if ALEKS use improved student achievement in mathematics. Yilmaz & Caruthers (2017) also tried to discover if there was a correlation between time spent in ALEKS and mathematics achievement. A total of 1,110 students enrolled in grades five through nine participated in the study during the 2014-2015 school year. More than 75% of the students were Latinx, 11% were White, and 9% were African American. The participants were divided into an experimental group which used ALEKS for 45 minutes daily and a control group which did not use ALEKS. All students were administered NWEA MAP assessments, and the results of the groups were compared. The study found that ALEKS use had a significant positive effect on student achievement. According to Yilmaz

& Caruthers (2017), "participation in ALEKS instruction explains approximately 5.5% of the variance in the end-of-year mathematics scores" on NWEA MAP (p. 86). However, no statistically significant relationship was found between time spent on ALEKS and student performance.

Review of the literature on ALEKS revealed that most of the studies have been conducted at the college level and very few at the K-12 level. The studies mostly focused on the effectiveness of ALEKS on student performance, student perceptions on ALEKS, or both. One common finding is that the researchers of the studies that measured perceptions of students and teachers on ALEKS report positive attitudes towards its use as a part of mathematics curriculum (Canfield, 2001; Hagerty & Smith, 2005; Stillson & Alsup, 2003; Taylor, 2008). In only one study the students felt frustrated because ALEKS did not follow the course textbook and it was considered time consuming (Xu et al., 2009). Hagerty and Smith (2005) also found ALEKS and textbook alignment to be one of the main student concerns.

The researchers who focused on the effectiveness of ALEKS in their studies reported mixed results on its effects on student performance in mathematics. According to some of these studies, the students who spent more time on ALEKS also had higher grades in class (Hampikian et al., 2007; Stillson & Alsup, 2003). However, this finding does not say much regarding the effectiveness of ALEKS on student performance. This could be because the students who are already successful in mathematics also spend time to complete their ALEKS assignments and consequently receive higher grades. ALEKS could be helpful for higher performing students, but not as effective with underperforming students.

A limited number of K-12 studies already makes it hard for school leaders to make research-based decisions in this area. The effects of ALEKS on student performance on the standardized assessments also remain unknown, as studies mostly report positive but not statistically significant findings. Mixed results of college level studies create another layer of complexity for the decision-making process, which often may lead the principals and superintendents to rely on the materials that have been created for commercial purposes by the company itself. The principals play an important role not only during a selection process of a certain technology but also during its implementation process. For this reason, the next section focuses on the role and responsibilities of educational leaders in technology use in schools.

Educational Leadership

Research indicates that school leadership, more specifically, principals play an important role in student achievement (Leithwood et al., 2004; Louis et al., 2010; Marzano & Waters, 2009; Waters et al., 2005). For example, according to Louis et al. (2010), "leadership is second only to classroom instruction as an influence on student learning" (p. 9). However, Hallinger and Heck (1996) claimed that it is not easy to identify the nature of this role and to what degree it affects student performance due to its complexity. To investigate this matter, Waters et al. (2005) analyzed 69 studies that were conducted on the relationship between school leadership and student achievement between 1970 and 2005. Meta-analysis of these studies involving 2,802 schools, 1.4 million students, and 14,000 teachers revealed that there is a statistically significant correlation of 0.25 between school leadership and student achievement. Furthermore, a later similar study involving 14 reports of the district-level leadership and student achievement from 1,210 districts found a correlation of 0.24 (Marzano & Waters, 2009).

In general, there has been a consensus among educators and policymakers throughout U.S. educational history that principals have an impact on student performance (Hallinger & Heck, 1996; Johnson, 2016). This belief seems to have been in place even when the empirical support from the recently conducted studies did not exist. However, the research suggests that the effects of school leadership on student performance may not necessarily be direct (Johnson, 2016; Leithwood et al., 2010). Supovitz et al. (2010) reported that the studies that explore this relationship can be divided into three categories:

> direct effects of leadership practice on student outcomes; mediated effects studies, in which principal leadership was mediated by other people, events, or organizational factors; and reciprocal effect studies, in which the relationships between leadership efforts and school and environmental factors were interactive. (p. 32)

To find the nature of the relationship between leadership and student outcomes, most studies identified certain mediators and measured their effects. Leithwood et al. (2010) tested how leadership influences student learning using a model that consists of Rational, Emotions, Organizational and Family paths. The researchers referred to this model as Four Paths and suggested that the leadership influence flows through these paths to enhance student performance. Two variables are identified to represent each one of these paths. The variables for the Rational Path were identified as academic press and disciplinary climate. These variables measure the leaders' competence, awareness, and expectations regarding curriculum, instruction, and discipline in the school. The variables that were used to represent the Emotions Path were collective teacher efficacy (CTE) and trust among the stakeholders. Instructional time and professional learning community were the two variables identified for the Organizational Path. Adult support and computer access at home were the two variables that represented family path. To measure the effects of these variables on student achievement, survey data from 1,445 teachers in 199 schools and achievement data in math and literacy for third and sixth grade students were used. The results of the study showed that Rational (0.26), Emotions (0.21) and Family Paths (0.26) had a significant and positive impact on student learning with similar effect size. One interesting finding was that the Organizational Path had the least influence on student learning despite being considered as the most influential path by the school leaders (Leithwood et al., 2010).

As the body of literature supporting the direct and indirect effects of school leadership on student achievement continues to grow, so does the list of the roles and responsibilities of a school leader along with the expectations. In the 20th century,

> principals are expected to be educational visionaries, instructional and curriculum leaders, assessment experts, disciplinarians, community builders, public relations and communication experts, budget analysts, facility managers, special program managers, as well as guardians of various legal, contractual, and policy mandates and initiatives. (Davis et al., 2005, p. 10)

As expectations of schools regarding student achievement grow and evolve, the principal’s role as an instructional leader is becoming increasingly important (Pannell & Sergi-McBrayer, 2020). For example, effective implementation of technology in schools is another responsibility that has been added to the list of roles and responsibilities of the principals relatively recently. According to Murphy (2017), “administrative leadership is probably the single most important factor affecting the integration of technology in schools” (p. 14).

Davis et al. (2005) studied eight pre- and in-service school leadership development programs in five states. According to one of the key findings of the study, principals impact student achievement mainly in two ways: hiring and developing effective teachers, and implementing effective organizational processes. The authors also argue that the list of expectations of the principal position may have grown to a degree that it is beyond the capabilities of any single individual. As the role of technology in education grows, it also becomes an inseparable part of creating and implementing effective organizational structures and processes within schools. Principals are not only expected to ensure the successful adoption and integration process of technology, but also stay up to date as it changes and evolves exponentially faster than teachers and students learn how to use it effectively.

The school leaders' responsibility of hiring and developing effective teachers is particularly important, as the research clearly demonstrates that the classroom teacher is the number one factor affecting student achievement (Blömeke et al., 2016; Marzano et al., 2005; Pannell & Sergi-McBrayer, 2020). Teacher knowledge and competence is considered an essential contributing factor of quality of instruction (Charalambous & Hill, 2012). Hill et al. (2008) studied the relationship between mathematical knowledge for teaching and mathematical quality of instruction, collecting data from 10 elementary and middle school teachers. Data were collected via various tools such as mathematical knowledge assessment, videotapes, interviews, and debriefings. The results indicated that mathematical quality of instruction is strongly, significantly, and positively associated with mathematical knowledge for teaching (Hill et al., 2008). In general, the quality of a teacher is mostly associated with the knowledge, skills, and effort rather than their education level and experience. Hanushek and Rivkin (2007) claimed that "the researchers have found wide variation in teacher quality, even among teachers with similar education and experience" (p. 81).

Hiring high quality teachers who will provide effective instruction in the classroom is one of the main challenges of school leadership. This challenge is bigger in urban schools, as teacher quality tends to be significantly lower in urban areas than in the suburbs (Jacob, 2007). Salaries, working conditions, and geographical proximity appear to be main contributing factors to teacher decisions when applying for teaching jobs. According to Hanushek and Rivkin (2007), working conditions such as facilities, safety, and quality of leadership, which tend to be worse in inner-city schools, affect teacher mobility more than the salary. To attract and keep quality teachers at their schools, principals must think of ways to make the building safer and more welcoming. This includes the physical beauty of the building as well as the relationships among staff. Providing strong quality leadership that teachers trust and value is also an important part of the equation.

In short, principals are expected to move the needle when it comes to student achievement. Their role as an instructional leader of the school has been trending up over the last two decades (Lavigne, 2020; Lynch, 2012). According to Pannell and Sergi-McBrayer (2020), a disconnect exists between the way the principals are trained in leadership preparation programs and the demands of the principal position in today's world. There is a growing concern among educational researchers regarding the quality of school leadership. Pannell and Sergi-McBrayer (2020) claimed that "the majority of school leaders are not equipped to successfully assume the responsibilities the job requires" (p. 2). Principal preparation programs in the universities are essential in preparing future principals for the job, especially for their role as the instructional leader of the school. To address the challenge of inadequate preparation, these programs are forced to focus increasingly on preparing principals for the instructional leader role and to look for innovative ways to constantly update their practices based on the most recent research.

Teacher evaluation and development are often considered as the main instructional leadership tasks of school principals (Goddard et al., 2019; Lavigne, 2020). According to Lavigne (2020), school leaders improve the quality of instruction in the classroom, which consequently impacts student learning, by observing and providing feedback to the teachers, guiding them towards relevant professional development opportunities, and evaluating their performance and growth over time. These practices are considered crucial in differentiating between effective and ineffective teaching. School leaders are expected to take necessary actions based on their observations and evaluations to enhance the quality of instruction in the classroom. These actions include having difficult conversations with teachers regarding ineffective instructional strategies, firing ineffective teachers who fail to demonstrate growth over a reasonable period of time, and actively looking to hire effective teachers to replace them.

As the instructional leaders of the building, principals are also responsible for providing necessary tools for teachers to increase their effectiveness. These tools often come in the form of technology, especially due to the rapid technological advancements in the last two decades as principals try to keep up with educational policy changes and the growing list of expectations as the result of these policy changes (Yilmaz & Caruthers, 2017). Academic literature on expectations of principals regarding technology mainly consists of recommendations based on the opinions of the authors (Anderson & Dexter, 2005). One such recommendation that appears to be a consensus among the experts in the field is that administrative oversight should be provided by the principals in order to achieve successful and effective implementation of technology in schools. National Educational Technology Standards for Administrators (NETS-A), published by the International Society for Technology in Education in 2002, is a comprehensive document that categorizes these recommendations and expectations for principals under six domains:

- Leadership and Vision
- Learning and Teaching
- Productivity and Professional Practice
- Support, Management, and Operations
- Assessment and Evaluation, and
- Social, Legal, and Ethical Issues

Each one of these domains includes a group of four to six standards known as National Educational Technology Standards for Administrators (NETS-A). Several states adopted this document as a guide for school and district leaders to implement technology programs in their schools (Anderson & Dexter, 2005).

A study conducted by Thomas and Knezek (1991) regarding the role of technology in schools is one of the exceptions in the academic literature due to its empirical nature. According to the authors, the purpose of this study was "to document the popular vision of educational leaders regarding the role technology can play in restructuring schools" (Thomas & Knezek, 1991, p. 266). A two-part survey was mailed to 240 teachers, administrators, and educational experts around the nation; 30% of the returned surveys were from 35 states. In the first part of the survey, the participants were asked to describe what they thought about the role of technology in learning, teaching, curriculum, leadership, and funding. The second part of the survey was about the level of necessary competency of school and district leaders for technology-related tasks. The respondents were asked to rate 33 pre-identified competencies. The analysis of the collected data showed that the degree of impact technology may have on restructuring schools depends on the school leader's competency level. For this reason, "a recurring theme among the respondents was the importance of training for instructional leaders in order to take advantage of technology's potential" (Thomas & Knezek, 1991, p. 271). Awareness and practice in finding information and resources about each competency was not considered sufficient. The school leaders were expected to exhibit mastery or experience in almost all 33 competencies.

Andersen and Dexter (2005) empirically explored "the role and relative importance of leadership compared to technology infrastructure and other characteristics of schools" (p. 55). In this study, the authors developed a model of technology leadership and tested it using data from a survey that was conducted nationally in 1998 by the staff of Teaching, Learning and Computing (TLC). The model that was developed by the authors viewed technology leadership as a mediator between the resources of the school and technology outcomes. The survey that was used to test this model was completed by 867 principals, 800 technology coordinators, and 4,100 teachers. Several indicators were identified to measure and define technology resources of the school, technology leadership, and technology outcome. The indicators that were identified to describe technology resources—also referred to as the infrastructure—of the school consist of the student-computer ratio, presence of high-speed internet access, and per-student technology expenditures. The presence of a technology committee, the number of days spent for technology planning, regular use of a technology such as e-mail to communicate with the stakeholders, professional development opportunities, budget for technology implementation and maintenance costs, district support of school's technology plan, grants received as an alternative way of technology funding, and the existence of an acceptable technology use policy were eight indicators that were chosen as the components to describe technology leadership. Technology outcomes were measured through the use frequency of email and internet among staff and students, the degree of technology integration in instruction, and the frequency of technology use to complete academic tasks. The researchers analyzed the nature of the relationship between technology resources, leadership, and outcomes. The study found that there was a positive significant correlation between technology leadership and technology outcome indicators. According to the authors, "the school's overall technology leadership score had a higher correlation with each technology outcome indicator than did all the infrastructure indicators with each technology outcome" (Anderson & Dexter, 2005, p. 70).

In a more recent study, Murphy (2017) explored the principal's role in implementing ALEKS in Algebra 1 courses. In this study, which was conducted in public schools in the state of South Carolina, Murphy (2017) defined the principal's role as a manager and instructional leader as the two of the most dominant roles throughout the last several decades, the latter becoming increasingly more dominant since the 1980s. Lately, the principal's role as a technology leader has become an important one, and it is growing at almost the same rate as technology itself. The principal's role as a technology leader has its roots in both management and instruction. Effective use of any technology in the classroom depends on the effectiveness of the leadership that is provided by the principal both prior to and during the implementation process (Murphy, 2017). Certain tasks such as purchase, installation, and maintenance fall under the management side of the principal's leadership, and the others, such as staff professional development, student training, curriculum alignment, and evaluation, fall under the instruction side. The principal's role as a technology leader emerges from the combination of these tasks and is "one of the most important factors affecting the effective use of technology in the classrooms" (Murphy, 2017, p. 18).

To identify the principal's role in the implementation of technology, Murphy (2017) conducted the Principals Technology Leadership Assessment (PTLA) survey and interviews with 15 high school principals who had implemented ALEKS in Algebra 1 classes in the last five years. One of the main themes identified as a result of this study was the professional development of the staff who would be implementing the technology in the classroom. Providing effective initial and ongoing trainings is a key to the successful implementation of technology. Another theme was the communication of a vision for the selected technology, which is crucial for stakeholder buy-in. The third theme was regarding "the proper hiring and employment of technical support staff" (Murphy, 2017, p. 104). To be able to get the desired results from a certain technology, the principal must ensure that the technical issues are minimal and are resolved in a timely manner.

School leaders are also responsible for connecting technology with culturally relevant instruction. Research shows that students are more engaged when they can culturally relate to the instructional materials (Brooks, 2006; Mayer, 2009). This is also true for educational technology. Joseph (2009) argued that a connection between educational technology and culturally relevant pedagogy is necessary to increase the engagement and consequently academic achievement for students of color.

While working to fulfill their responsibilities, especially when trying to increase the achievement for students of color, school leaders should also be mindful about gap gazing and deficit thinking. Decisions such as adopting a new curriculum or implementing a new technology for the sole purpose of closing achievement gaps may create a mindset that encourages making "subordinate populations more like dominant ones" rather than increasing their achievement (Gutiérrez & Dixon-Román, 2011, p. 23). According to Flores and Gunzenhauser (2021), "despite the growth of the concept of an opportunity gap, the concept is largely absent from the school leaders' talk" (p. 281). School leaders must be deeply familiar with the concept of the opportunity gap to be able to move schools toward a more equitable direction. They need to create systems and policies that are designed to address opportunity gaps and expose the disadvantaged students to similar educational experiences as their advantaged counterparts.

Although the direct link between school leadership, technology implementation, and student achievement is not clear and well established in empirical literature, experts in the field appear to agree on its existence. Certain standard behaviors that were discussed in this section can be adopted and demonstrated by the principals to support the effective and successful implementation of technology. ALEKS as a technological tool is one of the most used programs in mathematics classes, and school leadership is an important factor in its implementation. This study explores the relationship between ALEKS and student achievement. The aim of this research is to understand this relationship better. This chapter provided a larger context through four topics that were discussed: the history of mathematics instruction, student achievement, educational technology, and educational leadership.

CHAPTER 3

METHODOLOGY

The purpose of this study was to find the nature of the relationship between ALEKS and student achievement. To identify the existence of such a relationship, archived data were analyzed at a school that had been using ALEKS for more than six years. The study intended to identify if a correlation exists between students' progress on ALEKS and state test score improvement. The study school is a sixth through twelfth grade school in an urban charter school district in the Midwest. The district adopted ALEKS in the 2014-2015 school year and has been implementing it continuously since then. The district's primary goal in adopting this software as a part of its mathematics curriculum was to improve state test scores. However, its effectiveness has never been measured. The implementation of the program varies among the schools in the district mainly due to scheduling differences. The use of ALEKS has also changed and evolved at the study school. The changes in the implementation of ALEKS are discussed further in the following sections.

Research Design and Approach

This study used a one-group pre-test-post-test quasi-experimental research design to address the following research questions:

1. Is there a correlation between students' progress on ALEKS and their performance on standardized tests, before and after the implementation of ALEKS, at the middle school level?
2. Does a higher completion percentage on ALEKS increase the probability of scoring Proficient or Advanced on a state test?

The null hypotheses formed based on these questions are:

$H_{01:}$ There is no significant correlation between students' progress on ALEKS and their performance on the two standardized tests, before and after the implementation of ALEKS, at the middle school level.

$H_{02:}$ Mastering more topics on ALEKS does not increase students' likelihood of scoring at the Proficient or Advanced level on a state test.

This study qualifies as a quasi-experimental quantitative study because the participants are not randomly assigned to groups. For this study, the independent variable was students' progress using ALEKS during a regular school year which started in August and ended in May. The dependent variable was the difference between two mathematics state tests. The first state test that was taken in the spring of the previous school year was prior to ALEKS use, and therefore was considered a pre-test. The second state test was taken at the end of the academic year after ALEKS was used to prepare students for the test. This was considered a post-test. The difference between the post-test and pre-test scores was the dependent variable. A Pearson correlation was calculated to find how these two variables were related.

Setting and Participants

Setting

This study was conducted in an urban charter school district that consists of four campuses: K-3 elementary, 4-8 middle, 9-12 high and 6-12 middle/high school. There are approximately 1,500 students in the district, and the demographics are 64% Latinx, 27% African American, 7% White, and 2% Asian. The study focused only on the fourth campus, which serves approximately 300 students in sixth through twelfth grades. The demographics of the study school are significantly different from those of the district: 55% African

American, 35% Latinx, and 10% White and others. One hundred percent of the students at this school are enrolled in the Free and Reduced Lunch Program. All students except seniors are required to do work in ALEKS.

As mentioned above, the implementation of ALEKS has been different across the schools in the district. One of the main reasons for this variation is scheduling. For example, the study school uses an A day/B day calendar in which the students take four 90-minute classes every day, whereas the other middle school in the same district uses a regular five-day calendar in which the students take eight 45-minute classes every day. Another reason for the variation in implementation is the expectations of school leadership and how they view ALEKS. Such differences pushed the individual schools to develop their own implementation models at the beginning. Over the years as the teachers, principals, and district leadership became familiar with the program, the implementation became more standardized. The third reason for the implementation differences was the availability of technology as different schools had different devices such as iPads, laptops, or desktop computers, which added a different type of complexity or flexibility, depending on which type of device a school had.

For example, at the study school, the use of ALEKS has been through three major phases. In the first two years of adoption, the number of computer labs increased from two to four. The school did not have a reliable wireless internet connection at the time, so the principal decided to create two more computer labs with desktop computers that connected to the internet with wire. The district expectation was that all students except seniors must work on ALEKS. To accommodate this, creating new computer labs seemed to be a viable solution, which also matched with the principal’s view and expectations of ALEKS.

The district's expectation for mathematics instructional time is 90 minutes every day, which is double the common practice when compared to the other school districts in the area. When ALEKS was first adopted, it was expected to be used half of this allocated time. The students were required to spend 90 minutes every other day in computer labs working on ALEKS during their mathematics classes. Additionally, some students were required to stay for after-school and Saturday tutoring to work on ALEKS. This method of ALEKS implementation continued during the academic years of 2014-2015 and 2015-2016. These years were the first phase of ALEKS implementation.

The district purchased iPads and laptops and upgraded the wireless devices in school in August of 2016, which allowed students to work on ALEKS in their regular classrooms instead of going to the computer labs. This led to the second phase of implementation, in which the regular instruction happened in the first half of the mathematics period, and ALEKS was used in the second half of the 90-minute period every day. The students were still required to attend after-school tutoring, but Saturday tutoring stopped in the 2016-2017 and 2017-2018 years.

In both of these phases the teacher mainly acted as a supervisor while all students were actively working to complete their ALEKS goals. The teachers were there to assist if the students needed help. In other words, ALEKS was the primary driver of mathematics instruction in half of the time. In 2018-2019, the third phase, the district started pushing small group instruction during the second half of the mathematics classes. In this structure, the teacher was expected to pull a group of three or four students to go over a concept that they were struggling with based on assessment data. The remaining students were expected to work on their ALEKS goals. As the focus on small group instruction increased, ALEKS's role as the primary driver of instruction decreased, and it started to be viewed as another tool rather than the instructor.

In the beginning, ALEKS was not aligned with the district curriculum or pacing guide. The concepts that the students were learning in class as a whole group were significantly different from what they most likely were doing on ALEKS, because ALEKS is designed to provide individualized instruction. Eventually, the school district adopted a new curriculum and rearranged ALEKS topics based on the new curriculum. This created more alignment and standardization across the district over the years, and it is still an ongoing process.

Participants

For a reason that is discussed below, this study analyzed the data only for sixth, seventh and eighth grade students who took a middle school mathematics course. The target population of this study was urban middle school students in sixth, seventh and eighth grade who were taking a mathematics class below the level of Algebra 1. Students who took Algebra 1 in eighth grade were excluded from this study. The students who came or left in the middle of the school year were also excluded from this study. The accessible population was all of the middle school students, with the characteristics described above, at the study school. After filtering the archived data as described above, it was expected that ALEKS progress data for approximately 70-90 students for each year since the beginning of the implementation of ALEKS would be available.

Due to changes in state testing since 2014, not all the state test scores are comparable to the previous year's results. For example, in one year the state used a different scoring scale, and in another year the results were not reported at all. For the purpose of this study, the state test scores in two consecutive years needed to be on the same scale in order to calculate any improvement or difference in results. To overcome these discrepancies, the raw scores within each year were standardized. This enabled the years to be compared directly. During the first year of adoption, ALEKS data were not as properly tracked and archived as they were in later years, thus making them unavailable for analysis. Additionally, no tests were administered in the 2019-2020 school year due to the COVID-19 pandemic. This means that only the ALEKS data gathered during the academic years of 2015-2016, 2016-2017, 2017-2018, and 2018-2019 were analyzed to find answers to the questions of this study.

The ALEKS Program

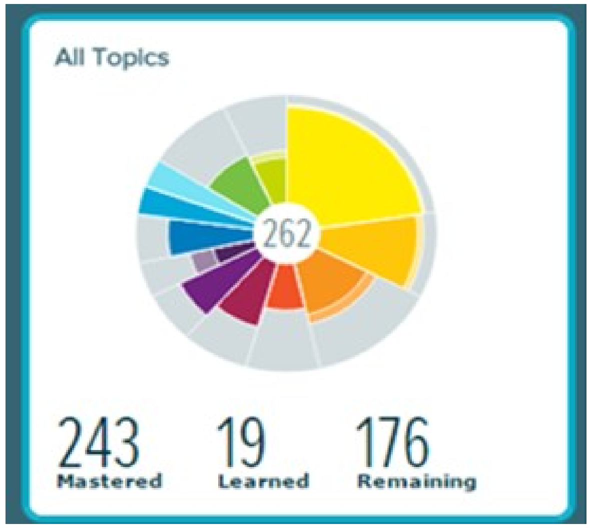
The implementation process started with the administration purchasing and setting up the accounts. Administrators, teachers, and students each have their own personal accounts with certain restrictions specific to the type of account. Once all of the accounts were created, the administration created the classes and assigned them to the teachers. After that, students were assigned to the classes, and then the subjects were assigned to classes. The same or different subjects can be assigned to individual students who are in the same class. For example, teachers can assign either seventh grade Math topics to every student in seventh grade, or they can choose to assign seventh grade Math topics to some students and sixth or eighth grade Math topics to other students within the same class. This flexibility helps teachers to differentiate the instruction. Math teachers were able to monitor the progress of the students who were assigned to them.

Students received a brief tutoring on how to use ALEKS when they logged in for the first time. This interactive tutorial taught them how to input their answers, graph a point, draw a geometric shape, and so forth before they started using the software. After this brief tutoring, students took an ALEKS assessment with all free response questions; this assessment is called the Initial Knowledge Check. There are approximately 30 questions on this initial assessment. The difficulty of each next question is adjusted based on the student's answers to previous questions. At the end of the initial assessment, ALEKS identifies the student's knowledge state—the topics that the student already knows and the topics that the student needs to learn. ALEKS summarizes its report for the assessment in a color-keyed pie chart (see Figure 3.1).

Each slice is colored differently and represents various sections of the subject. For example, there are 438 topics in sixth grade level math. These topics are grouped under twelve major categories: Whole numbers; Decimals; Fractions; Ratios, Proportions and Measurement; Percents; Integers and Rational Numbers; Equations and Inequalities; Graphs and Functions; Angles, Lines, and Polygons; Transformations; Perimeters, Areas, and Volumes; Data Analysis and Probability. The grey portions are the parts that the student still needs to learn. The darker color in each slice shows the portion that the student has already mastered. The lighter color in each slice shows the portion that student has learned but not mastered yet. Students master some of the topics as a result of the initial assessment. These are the topics ALEKS identifies as "students already know."

Figure 3.1

ALEKS Pie Chart



After the assessment, students enter the Learning Mode. In this mode, students are given choices to work on. The choices are derived from the topics ALEKS identifies as "student is ready to learn." There are five problems for each topic that the student needs to answer correctly. As stated above, ALEKS mathematics does not use multiple choice questions. The questions are open-ended and instead of using paper and pencil, students input their answers to these open-ended questions through their keyboard, mouse, or touch screen device using the virtual tools provided on the screen. After students input the answers, ALEKS evaluates their responses and gives them immediate feedback. When a student inputs an incorrect answer, the system assigns extra similar problems. Students can click on a button titled "Explanation" if they do not know how to answer the question. Some topics have multiple explanations from which students can learn. Most of the topics include video clips that the students can click and watch for a brief instruction of the topic they are working on. After students learn a specified number of topics (around 20) the system automatically assigns an assessment for the topics learned. The teacher can assign an assessment as well. These assessments are called Knowledge Checks and have between 25 and 30 problems. With the Knowledge Check, the system checks to see if a student actually learned the topic. At the end of the Knowledge Check, ALEKS gives immediate feedback to the student about how many of the previously learned topics have been mastered and how many of them need to be revisited.

Students' ALEKS progress is monitored closely by teachers and administration. Incentives are put in place to encourage students to show 20% progress for each quarter. ALEKS progress is entered as a grade for mathematics courses. Students have the flexibility to complete the topics in Learning Mode from home, but they can take Knowledge Checks only when they are at school.

Data Processing and Analysis

As mentioned above, this study intended to find answer to two research questions.

1. Is there a correlation between students' progress on ALEKS and their performance on standardized tests, before and after the implementation of ALEKS, at the middle school level?
2. Does a higher completion percentage on ALEKS increase the probability of scoring at the Proficient or Advanced level on a state test?

To answer the first question, the analysis of data was conducted as follows. ALEKS progress was the independent variable of this study. ALEKS progress is simply the student's progress based on the Initial Knowledge Check. For example, if a student in the sixth grade scores 20% on the Initial Knowledge Check, it means that student already has 20% mastery of the sixth grade topics. After completing topics in the Learning Mode and mastering them as evidenced by the Knowledge Checks throughout the year, the student's score reaches 83%. This shows a 63% improvement during the year. It is possible that some students may complete sixth grade math and move on to seventh grade topics in the same year. Because of this, it is possible for a student to show more than 100% growth.

The dependent variable of this study was the difference in state test scores. As discussed above, the test scores have been reported on different scales since 2014 due to the changes in the assessment program. For this reason, the difference between the scores in two consecutive years does not allow a valid analysis. To overcome this issue, the scores were standardized within each year. Afterwards, the difference was found and its correlation with ALEKS progress was calculated. These calculations were conducted for each academic year separately as well as for all years combined.

The goal in finding the difference between pre- and post-tests is to calculate how each student's test score improved. Tables 3.1, 3.2, and 3.3 show the scoring scales that were used to report the results in different years. Below are the scoring scales that the state used for sixth, seventh and eighth grade mathematics tests.

Table 3.1

State Test Scoring Scale in 2015

	Below Basic	Basic	Proficient	Advanced
Grade 6	Below 2473	2473-2551	2552-2609	2610+
Grade 7	Below 2484	2484-2566	2567-2634	2635+
Grade 8	Below 2504	2504-2585	2505-2652	2653+

Table 3.2

State Test Scoring Scale in 2016 and 2017

	Below Basic	Basic	Proficient	Advanced
Grade 6	350-469	470-517	518-554	555-570
Grade 7	360-481	482-527	528-563	564-740
Grade 8	390-495	496-543	544-571	572-770

Table 3.3

State Test Scoring Scale in 2018 and Later

	Below Basic	Basic	Proficient	Advanced
Grade 6	260-387	388-416	417-437	438-580
Grade 7	270-393	394-434	435-461	462-600
Grade 8	310-419	420-467	468-505	506-660

As can be seen on the tables above, the scoring scales in 2016 and 2017 as well as in 2018 and 2019 are on a continuum. This allows the comparison of the scores without converting them into standardized scores for certain years. For example, if a student scored 415 in May 2018 when they were in sixth grade and 435 in May 2019 when they were in seventh grade, it means this student improved 20 points on this scale. By comparing this improvement to the student's ALEKS progress during the year, this study intended to clarify if the use of the program made any difference.

The reason this study does not focus on high school is because the Algebra 1 end-of-course assessment is completely different from the grade level assessments. Calculating the improvement as in the previous paragraph is not reliable due to this difference. Also, Geometry and Algebra 2 state tests are not mandatory for all students to take, and they are given only to a few selected students every year. On the contrary, grade level state assessments in middle school have more similarities, making it possible to calculate the improvement.

Mean and standard deviation of the data were calculated as part of the preliminary analysis. Pearson correlation and simple regression analysis are the suggested methods to analyze this data. Statistical significance in this case means that the student's ALEKS progress predicts improvement on a state test score to a certain degree.

To answer the second question, whether a higher completion percentage on ALEKS increases the probability of scoring Proficient or Advanced on a state test, the data were analyzed further to find if more ALEKS completion would make it more likely for a student to score at the Proficient or Advanced level on a state test. Firstly, Pierson correlation was calculated between ALEKS completion and state test scale score. Then the correlation was calculated between ALEKS completion and achievement level for each student. There are four levels of achievement: Below Basic, Basic, Proficient, Advanced.

Ethical Considerations

The researcher who conducted this study is an administrator at the study school district. This means that the researcher has direct access to the archived data that were analyzed for the purpose of this study. There was no contact or communication with students so this study qualified for Exempt IRB Review. Many of the ethical considerations are removed without the involvement or identification of human subjects. However, having direct access to archived data as an administrator in the district raises ethical concerns regarding the researcher's power. These concerns were addressed by obtaining necessary permissions in writing from the superintendent. All identifiable information was removed before the researcher received the data. All data were saved in a password-protected device that could be accessed only by the researcher. Data were only collected, stored, and analyzed after the IRB approval was received.

CHAPTER 4

RESULTS OF ANALYSIS AND CONCLUSIONS

The purpose of this study was to identify the nature of the relationship between middle school students' ALEKS progress and their performance on mathematics state tests. As stated in Chapter 3, two hypotheses were tested in this study:

> H_{01}: There is no significant correlation between students' progress on ALEKS and their performance on the two standardized tests, before and after the implementation of ALEKS, at the middle school level.
>
> H_{02}: Mastering more topics on ALEKS does not increase students' likelihood of scoring at the Proficient or Advanced level on a state test.

Archived data from a Midwest urban school were used to test these hypotheses. Descriptive statistics for the data are provided at the start of this chapter, followed by hypothesis tests and the conclusions derived therefrom.

Participants

The data used in this research were collected during the school years of 2015-2016, 2016-2017, 2017-2018 and 2018-2019. Only the middle school students in sixth, seventh, and eighth grades who attended this school the full year and had grade level mathematics state test scores available for at least two consecutive years—current and previous—were included in the study. Students who withdrew from the school during a particular school year were excluded from the study. The students who did not take the state test prior to using ALEKS due to the reasons such as attending an out-of-state school or being absent on the test day, were also excluded from the data that were analyzed. Applying this filtering criteria revealed that the data for 84 students in 2015-2016, 73 students in 2016-2017, 91 students in 2017-2018, and 88 students in 2018-2019 school years were available for analysis. Some of these students were the same participants, because they were promoted to the next grade level working on ALEKS for two or three years depending on if they started attending the school in seventh or sixth grade. A separate analysis for these students may be conducted to identify if more than one year of exposure to ALEKS had any impact on their final state test performances. This can be a longitudinal follow-up study in the future.

Tables 4.1, 4.2, and 4.3 show the distribution of the participants by grade level, race/ethnicity and gender. Table 4.1 shows that the number of eighth grade students in the first two years was approximately half the number of eighth grade students in the last two years. The reason for this was because the other half of the eighth graders in 2015-2016 and 2016-2017 took the state Algebra 1 end-of-course assessment instead of the grade level state assessment. The Algebra 1 course is typically offered at the high school level, more specifically in ninth grade at this school. But in 2015-2016 and 2016-2017, some eighth grade students were offered the opportunity to take the Algebra 1 course and consequently took the state end-of-course assessment for that subject. This practice has stopped since the 2017-2018 school year, and all eighth grade students have been taking the grade level state assessment since then.

Table 4.1 also shows that there were 50 students in seventh grade in 2015-2016, which is higher than the other years. This is because the school had three sections of seventh grade in that year. Due to enrollment issues, the number of sections was dropped to two after that year. Historically, sixth grade enrollment has been a struggle at this school where, on average, 15 students enroll each year. The main cause of low enrollment in sixth grade is that all of the other elementary schools in the area are kindergarten through sixth grade, and parents prefer not to move their children to this sixth through twelfth grade school in their last year. The district has plans to open a feeder school to resolve this issue.

Table 4.1

Participants by Grade Level

	Frequency			Percent		
	6th Grade	7th Grade	8th Grade	6th Grade	7th Grade	8th Grade
2015-2016	12	50	22	14.29	59.52	26.19
2016-2017	18	37	18	24.66	50.68	24.66
2017-2018	9	38	44	9.89	41.76	48.35
2018-2019	11	36	41	12.50	40.91	46.59
Total	50	161	125	14.88	47.92	37.20

As Table 4.2 shows, more than 90% of the participants in this study were African American and Latinx students in each year. In Chapter 3, it was mentioned that the school demographics of this sixth-twelfth grade school are 55% African American, 35% Latinx, and 10% White and others. However, this is slightly different for the participants of this study, as the data show more than 50% of them were Latinx. This shows that the middle school sixth-eighth grade demographics is different than the high school ninth-twelfth grade demographics, thus affecting the overall demographics data of the school.

Table 4.2

Participants by Race/Ethnicity

	Frequency				Percent			
	Black	Latinx	White	Asian	Black	Latinx	White	Asian
2015-2016	44	37	3	0	52.38	44.05	3.57	0.00
2016-2017	32	39	2	0	43.84	53.42	2.74	0.00
2017-2018	40	47	3	1	43.96	51.65	3.30	1.10
2018-2019	40	45	2	1	45.45	51.14	2.27	1.14
Total	156	168	10	2	46.43	50.00	2.98	0.60

Table 4.3 shows that there were more male participants in the first two years and more female participants in the third year. In the 2018-2019 school year, male and female participants were equally distributed.

Table 4.3

Participants by Gender

	Frequency		Percent	
	Male	Female	Male	Female
2015-2016	45	39	53.57	46.43
2016-2017	39	34	53.42	46.58
2017-2018	40	51	43.96	56.04
2018-2019	44	44	50.00	50.00
Total	168	168	50.00	50.00

Overall, there were 336 data points available total in the four years to be analyzed (see Table 4.4). However, as mentioned above, some of these data points belonged to the same individuals over the course of four years. Analysis of these data revealed that there were a total of 225 individual students. Of these 225 individuals, 137 worked on ALEKS for one year, 63 for two consecutive years, and 25 for three consecutive years between 2015 and 2019. Additionally, some of the 1-year or 2-year students might have used it for another year in 2014-2015. However, 2014-2015 was the first school year ALEKS was adopted, and the data were not tracked and recorded as they were in later years. Unavailability of the data for 2014-2015 made it impossible to know the ALEKS progress of the participants who were enrolled in sixth or seventh grade and used ALEKS during this year. For this reason, only the data between 2015 through 2019 school years were included in the analysis when one-, two-, or three-year effects of ALEKS use on the state test performance were investigated.

Table 4.4

Participants in Each Academic Year

Years	Participants
2015-2016	84
2016-2017	73
2017-2018	91
2018-2019	88
Total	336

Statistical Analysis and Data Tables

Statistical analysis of four data sets was conducted separately for each school year. Tables 4.5–4.8 show the descriptive statistics for dependent and independent variables for all four school years.

Table 4.5

Descriptive Statistics for School Year 2015-2016

	N	Min.	Max.	Mean	Std. Deviation
Pre-test – May 2015	84	2237	2644	2455.00	82.00
Post-test – May 2016	84	360	598	483.58	49.40
ALEKS Progress 2015-2016	84	20	95	51.88	15.62

Table 4.6

Descriptive Statistics for School Year 2016-2017

	N	Min.	Max.	Mean	Std. Deviation
Pre-test – May 2016	73	350	571	463.16	46.09
Post-test – May 2017	73	350	577	475.88	43.48
ALEKS Progress 2016-2017	73	17	110	49.26	16.48

Table 4.7

Descriptive Statistics for School Year 2017-2018

	N	Min.	Max.	Mean	Std. Deviation
Pre-test – May 2017	91	310	520	463.16	39.91
Post-test – May 2018	91	350	577	475.88	42.78
ALEKS Progress 2017-2018	91	10	136	42.35	18.05

Table 4.8

Descriptive Statistics for School Year 2018-2019

	N	Min.	Max.	Mean	Std. Deviation
Pre-test – May 2018	88	284	483	401.92	33.33
Post-test – May 2019	88	318	548	432.36	41.21
ALEKS Progress 2018-2019	88	16	79	43.88	13.77

As can be seen in Tables 4.5–4.8, also mentioned in Chapter 3, the scoring scales for the pre- and post-tests were different in three of the four years. Because of this, the scores were standardized using z-scores to conduct the analysis. The difference between the two sets of scores was calculated to find the growth between the two state assessments; then the Pearson correlation was calculated between the ALEKS progress throughout the year and the growth in state assessments.

Since the 2016-2017 and 2018-2019 school year pre- and post-test scoring scales were on a continuum, the analysis for those years was also conducted both ways, with and without standardizing the scores. Doing this was helpful to draw more accurate conclusions within each year and also to make comparisons across the years. Tables 4.9–4.14 show the Pearson correlations between the ALEKS progress and growth between pre- and post-tests for each year.

Table 4.9

Pearson Correlation between Variables in 2015-2016 (Using Z-scores)

	ALEKS Progress	State Test Growth
ALEKS Progress		
State Test Growth	.21	

Note. p = .06 (2-tailed); N = 84

Table 4.10

Pearson Correlation between Variables in 2016-2017 (Using Scale Scores)

	ALEKS Progress	State Test Growth
ALEKS Progress		
State Test Growth	.37**	

Note. ** $p < .01$ (2-tailed); N = 73

Table 4.11

Pearson Correlation between Variables in 2016-2017 (Using Z-scores)

	ALEKS Progress	State Test Growth
ALEKS Progress		
State Test Growth	.40**	

Note. ** $p < .01$ (2-tailed); N = 73

Table 4.12

Pearson Correlation between Variables in 2017-2018 (Using Z-scores)

	ALEKS Progress	State Test Growth
ALEKS Progress		
State Test Growth	.19	

Note. $p = .07$ (2-tailed); N = 91

Table 4.13

Pearson Correlation between Variables in 2018-2019 (Using Scale Scores)

	ALEKS Progress	State Test Growth
ALEKS Progress		
State Test Growth	.17	

Note. $p = .11$ (2-tailed); N = 88

Table 4.14

Pearson Correlation between Variables in 2018-2019 (Using Z-scores)

	ALEKS Progress	State Test Growth
ALEKS Progress		
State Test Growth	.07	

Note. $p = .51$ (2-tailed); N = 88

The Pearson correlation was calculated for the combined data after the test scores were standardized for all years.

Table 4.15

Pearson Correlation between Variables for Combined Data (Using Z-scores)

	ALEKS Progress	State Test Growth
ALEKS Progress		
State Test Growth	.20**	

Note. ** $p < .01$ (2-tailed); N = 336

Pearson correlations were also found between the ALEKS progress throughout each year and the state test performance at the end of the year.

Table 4.16

Pearson Correlation between Variables in 2015-2016

	ALEKS Progress	Post-test Performance
ALEKS Progress		
Post-test Performance	.41**	

Note. ***p* < .01 (2-tailed); N = 84

Table 4.17

Pearson Correlation between Variables in 2016-2017

		ALEKS Progress	Post-test Performance
ALEKS Progress	Pearson Correlation		
Post-test Performance	Pearson Correlation	.54**	

Note. ***p* < .01 (2-tailed); N = 73

Table 4.18

Pearson Correlation between Variables in 2017-2018

	ALEKS Progress	State Test Performance
ALEKS Progress		
State Test Performance	.27**	

Note. ***p* < .01 (2-tailed); N = 91

Table 4.19

Pearson Correlation between Variables in 2018-2019

	ALEKS Progress	Post-test Performance
ALEKS Progress		
Post-test Performance	.49**	

Note. ***p* < .01 (2-tailed); N = 88

Pearson correlations between ALEKS Progress and post-test scores as well as ALEKS Progress and pre-test scores for combined data were also calculated.

Table 4.20

Pearson Correlation between Variables for Combined Data (with Z-scores)

	ALEKS Progress	Post-test Performance
ALEKS Progress		
Post-test Performance	.40**	

Note. ***p* < .01 (2-tailed); N = 336

Table 4.21

Pearson Correlation between Variables for Combined Data (with Z-scores)

	ALEKS Progress	Pre-test Performance
ALEKS Progress		
Pre-test Performance	.22**	

Note. ***p* < .01 (2-tailed); N = 336

Hypotheses Testing

The first hypotheses to be tested was:

H_{01}: There is no significant correlation between students' progress on ALEKS and their performance on the two standardized tests, before and after the implementation of ALEKS, at the middle school level.

Table 4.22

Summary of Pearson Correlations between ALEKS Progress and Growth on State Assessments during each School Year

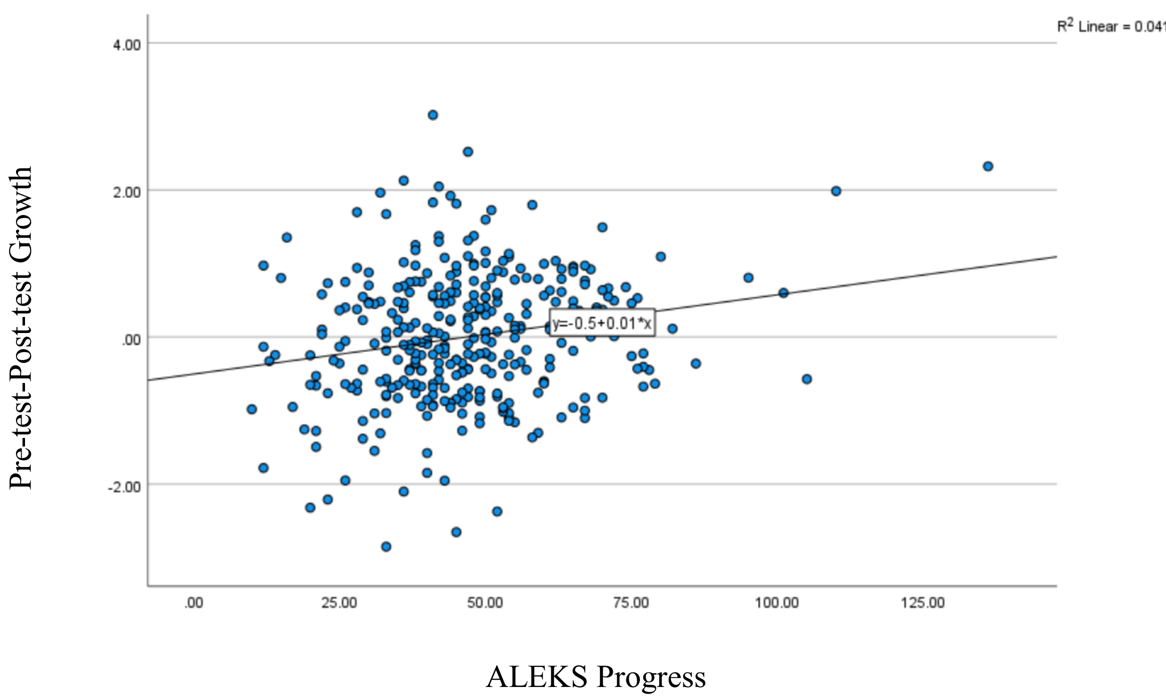
	2015-2016	2016-2017	2017-2018	2018-2019	Combined
ALEKS Progress	.21	.40** (.37**)	.19	.07 (.17)	.20**

Note. ***p* < .01 (2-tailed); **p* < .05 (2-tailed)

The analysis showed that there was a positive correlation between ALEKS progress and growth on the performances between two consecutive state assessments. When the data were combined for all four years and the correlation was calculated between ALEKS Progress and the difference between post- and pre-tests (growth) was calculated, positive significant correlation was found, $r(334) = .20, p < .01$. However, when the correlations were calculated for each year separately, only the 2016-2017 year showed a significant positive correlation, $r(71) = .40, p < .01$. The results for the other three years showed positive correlations, but not significant. A complete list of correlations is presented in Table 4.21. A scatterplot of combined ALEKS progress and state test growth is presented in Figure 4.1.

Figure 4.1

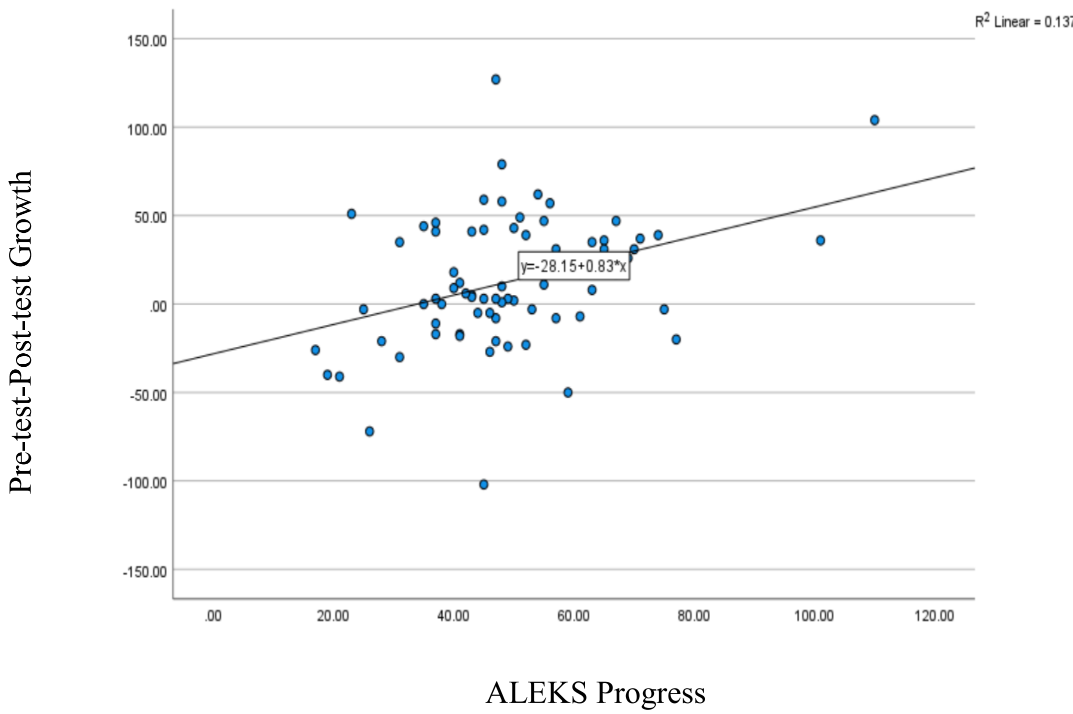
Combined Data: ALEKS Progress and Pre-test-Post-test Growth



The scatter plot of 2016-2017 data is presented in Figure 4.2.

Figure 4.2

2016-2017 ALEKS Progress and Pre-test-Post-test Growth



These results show that the null hypothesis may be rejected when all years are combined and analyzed together. However, when analyzed separately, the null hypothesis may only be rejected for the 2016-2017 school year.

The second hypothesis was also tested using Pearson correlation. This time, the correlations between ALEKS progress and the performance on the state tests that were taken at the end of the year were found:

H_{02}: Mastering more topics on ALEKS does not increase students' likelihood of scoring at the Proficient or Advanced level on a state test.

Table 4.23

Summary of Pearson Correlations between ALEKS Progress and Post-test Scores

	2015-2016	2016-2017	2017-2018	2018-2019	Combined
ALEKS Progress	.41**	.54**	.27**	.49**	.40**

Note. ***p* < .01 (2-tailed)

Significant positive correlations were found between ALEKS progress and post-test scores across all years separately as well as combined. Additionally, average ALEKS progress in each achievement level category was found to test the second hypothesis.

Table 4.24

ALEKS Progress Based on Achievement Levels

	N	Min.	Max.	Mean	Std. Deviation
Below Basic	117	10.00	136.00	40.90	17.26
Basic	150	12.00	105.00	46.85	13.99
Proficient	53	25.00	101.00	55.04	15.71
Advanced	16	13.00	86.00	58.69	16.95

A two-sample t-test was conducted between Below Basic/Basic and Proficient/Advanced categories to find if ALEKS progress means were significantly different between the two categories. The results showed that there was a significant difference in mean ALEKS progress between the students who scored Below Basic/Basic and Proficient/Advanced ($t_{104.897} = 5.416$, $p < .001$).

Table 4.25

ALEKS Progress Based on Achievement Levels (Continued)

	Achievement Levels	N	Mean	Std. Deviation	Std. Error Mean
ALEKS Progress	Below Basic/Basic	267	44.24	15.75	.96
	Proficient/Advanced	69	55.88	15.95	1.92

Figures 4.3–4. 7 are the scatterplots of the analyzed data.

Figure 4.3

Combined Data: ALEKS Progress and Post-test Performance

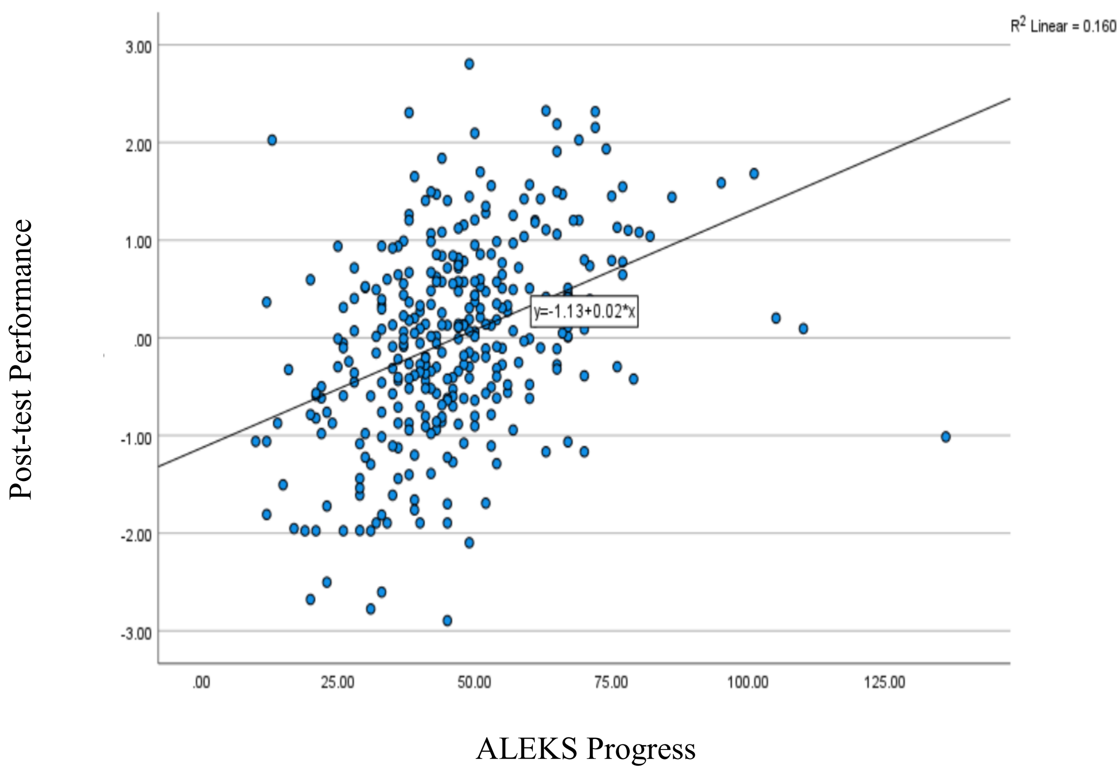


Figure 4.4

2015-2016 ALEKS Progress and Post-test Performance

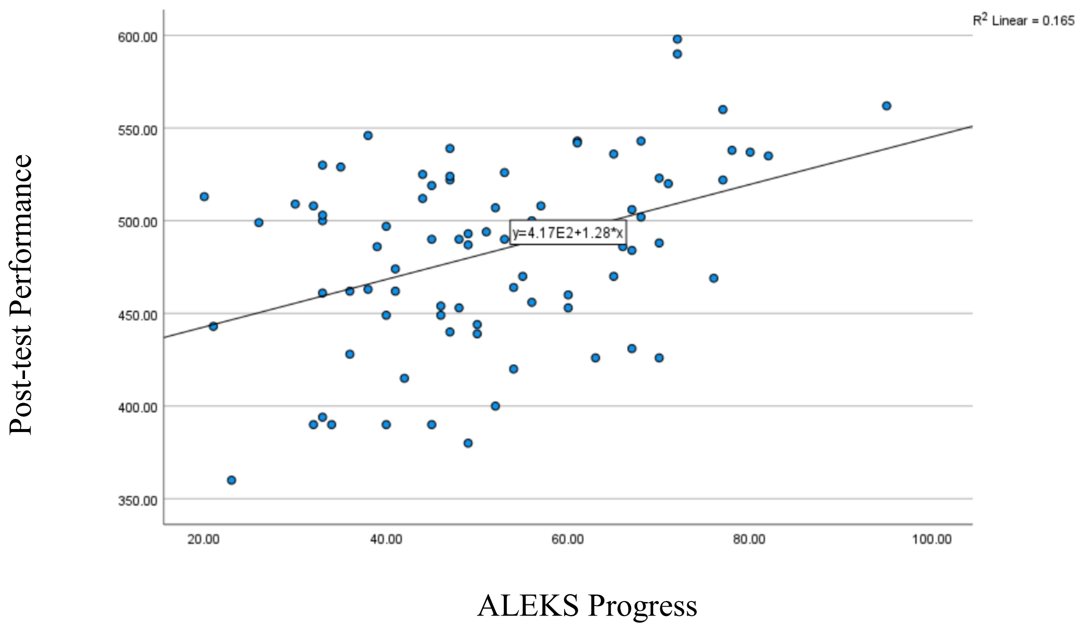


Figure 4.5

2016-2017 ALEKS Progress and Post-test Performance

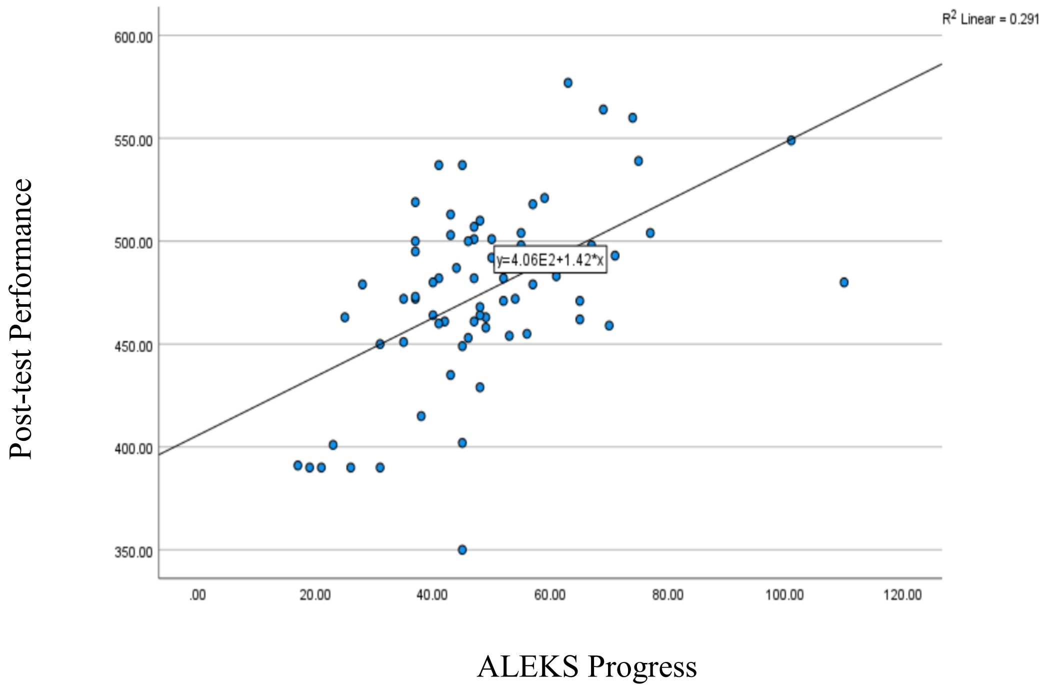


Figure 4.6

2017-2018 ALEKS Progress and Post-test Performance

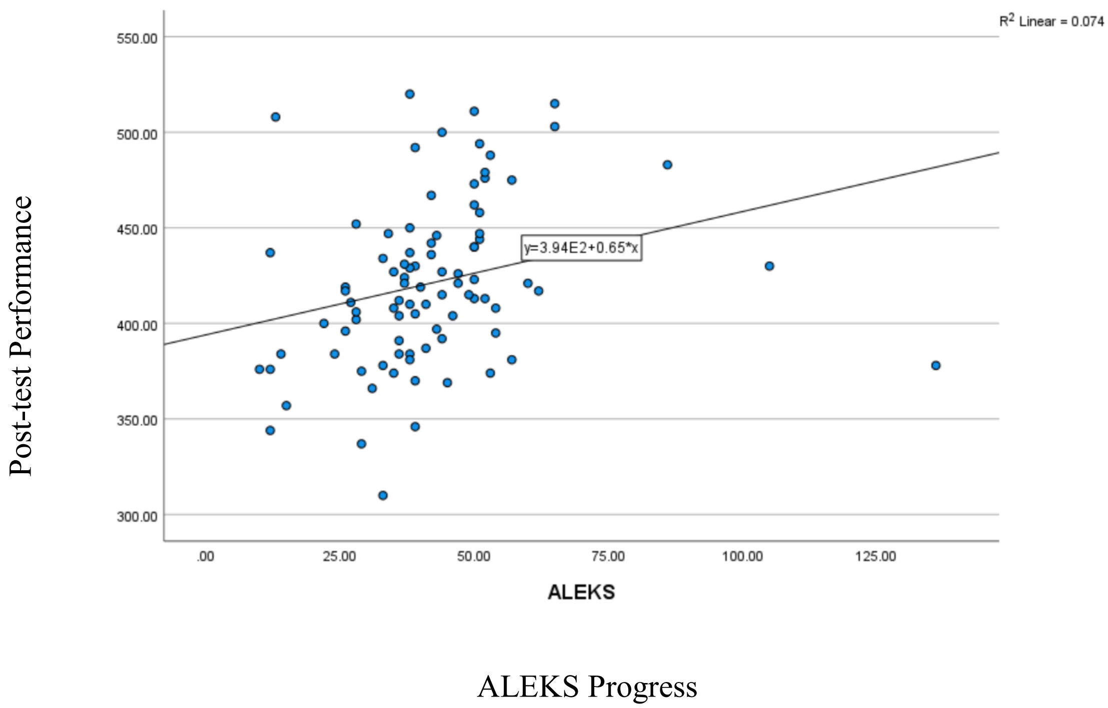
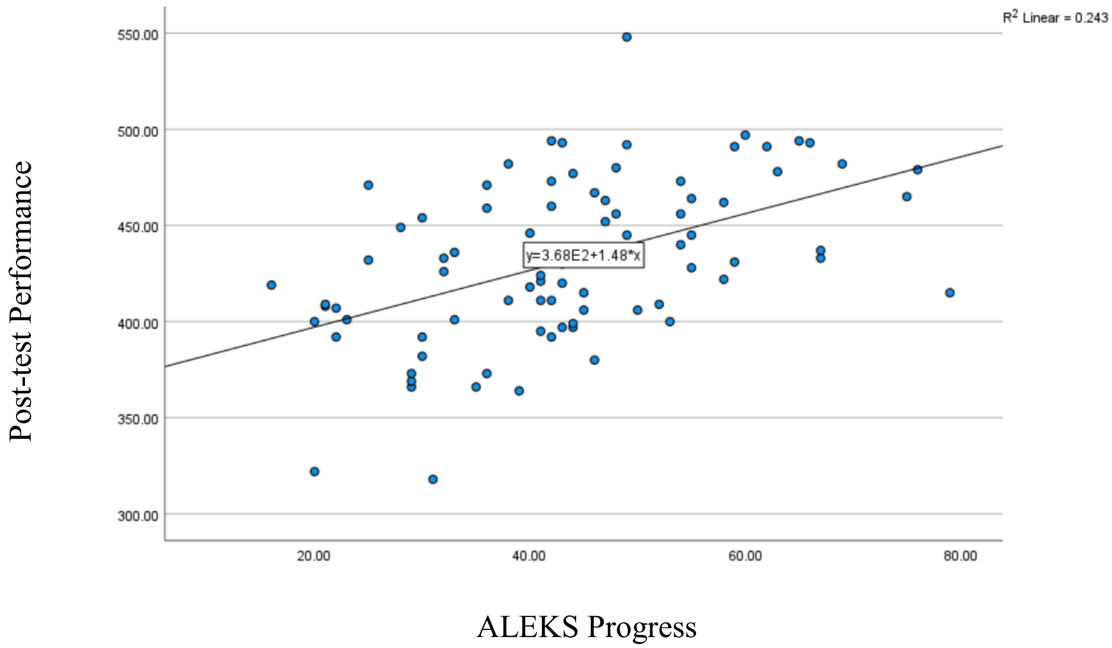


Figure 4.7

2018-2019 ALEKS Progress and Post-test Performance



As presented in Table 4.19, there is a significant correlation between ALEKS progress and post-test scores, r(334) = .40, p < .01. There is also a significant correlation between ALEKS progress and pre-test scores, r(334) = .22, p < .01. This means that the correlation increased by approximately .18 after ALEKS was used. Additionally, Table 4.23 shows that the students who scored Proficient and Advanced on post-tests, progressed more on ALEKS, 55.04 and 58.69% on average respectively, than the students who scored Below Basic and Basic, 40.90 and 46.85% on average respectively. The results showed that the students who progressed more on ALEKS were more likely to score at a higher achievement level such as Proficient and Advanced. Hence, the second null hypothesis maybe rejected as well.

ALEKS progress and state test performance data were analyzed for various demographic groups such as race and gender. The sample size for certain groups of students such as White and Asian was very small. This made the comparison of data possible only for African-American and Latinx students. Independent-samples t-tests were conducted to find if there were any differences in mean ALEKS progress and post-test scores between female and male students. No significant differences were found in any year. Table 4.25 shows the averages by gender.

Table 4.26

Averages by Gender

		2015-2016		2016-2017		2017-2018		2018-2019	
	Gender	N	Mean	N	Mean	N	Mean	N	Mean
Post-Test Scores	F	39	473.77	34	476.73	51	414.37	44	429.23
	M	45	492.09	39	475.12	40	430.22	44	435.50
ALEKS Progress	F	39	53.18	34	49.53	51	42.39	44	42.47
	M	45	50.76	39	49.03	40	42.30	44	45.27

This study involved students from four racial/ethnic groups. However, the sample sizes for Asian and White students were very low, between zero and three students in each year. If there were more students in these groups, ANOVA test would have been conducted to find the mean differences among more than two groups. Since the sample sizes were low for these two groups, the mean differences were analyzed using an independent-samples t-test only between Black and Latinx students. No significant differences were found for ALEKS and post-test scores across all years.

Table 4.27

Averages by Race

		2015-2016		2016-2017		2017-2018		2018-2019	
	Race	N	Mean	N	Mean	N	Mean	N	Mean
Post-Test Scores	A	-	-	-	-	1	483.00	1	548.00
	B	44	485.68	32	482.68	40	409.50	40	431.78
	L	37	480.08	39	470.13	47	429.79	45	429.80
	W	3	496.00	2	479.00	3	426.33	2	444.00
ALEKS Progress	A	-	-	-	-	1	86.00	1	49.00
	B	44	52.75	32	52.88	40	42.80	40	44.60
	L	37	50.73	39	46.64	47	41.17	45	42.38
	W	3	53.33	2	42.50	3	40.33	2	60.50

Conclusions and Summary

The results of analysis show that a statistically significant positive correlation existed between students' ALEKS progress and growth in state assessments when data were combined for all four academic years. However, when the years were analyzed separately, only the 2016-2017 school year had a statistically significant positive correlation. This means that the students' state assessment scores showed growth from the May 2016 test to the May 2017 test, and this growth may be due to the way ALEKS was implemented during 2016-2017.

Significant positive correlations existed between ALEKS progress and post-test scores for each school year separately as well as all four years combined. This means that students who progressed more on ALEKS also scored better on the state assessments than their peers with less ALEKS progress.

The results of these analyses are discussed further in the next chapter. Chapter 5 also focuses on the educational implications of these results, limitations of this study, and recommendations for future research.

CHAPTER 5

DISCUSSION

This study was designed to determine the nature of the relationship between ALEKS and student achievement. The percentage of the topics students mastered from the beginning until the end of the school year was defined as ALEKS progress and used to determine if it has any effects on student achievement. Students' state test scores were used to define student achievement. The findings reported in the previous chapter indicate that students' ALEKS progress positively correlates with their growth and performance on the state assessments. The findings of this study are interpreted in this chapter along with their implications on the use of educational technology in mathematics classes.

Summary of the Study

The combination of ongoing pressure from policy makers regarding student achievement and advancements in educational technology in the last two decades has created a need among school leaders to look for solutions that will produce favorable results in a short period of time. One such potential solution, according to some educators, is ALEKS, a web-based software program that is predominantly used in K-12 and college level mathematics classrooms around the nation. ALEKS uses artificial intelligence and is built on a well-researched knowledge space theory (Falmagne et al., 1990). Although the program was built on a credible theory, there is not sufficient evidence in academic literature that supports its effectiveness. As mentioned in previous chapters, this makes school leaders rely solely on the promotional materials that are released by the company itself when adopting ALEKS. For this reason, limited independent and objective evaluation of ALEKS within academic literature is the central problem of this study. Despite its limitations that are discussed in more detail below, this study intends to contribute to closing a gap in academic literature not only regarding ALEKS but also in evaluating educational technology in general.

The theoretical framework of this study consisted of four aspects of education: curriculum and instruction in mathematics, student achievement, educational technology, and educational leadership. Each one of these topics is discussed thoroughly in Chapter 2 and the interdisciplinary nature of this study has been established through highlighting the connections among these topics. Being adopted as part of the mathematics curriculum by school leaders around the nation makes ALEKS an interesting and relevant tool to be analyzed through the lenses of disciplines of educational leadership and curriculum and instruction.

The purpose of this study was to bring clarity to the nature of the relationship between ALEKS progress and student achievement. Two research questions were formulated to investigate the existence of this relationship. To answer the research questions, archived data regarding ALEKS progress and state test scores for middle school students were requested and obtained for each participant from the district administration once IRB approval was received.

The received data were from 2015-2016, 2016-2017, 2017-2018 and 2018-2019. The state testing was cancelled in the 2019-2020 school year due to COVID-19 pandemic; therefore state test scores were not available for this school year. Additionally, the school was virtual in the 2020-2021 school year, and a new virtual platform was adopted to accommodate student needs for all subjects. Because of this, the use of ALEKS was suspended temporarily during the 2020-2021 school year, thus making the ALEKS progress data unavailable for analysis. Schools continued using ALEKS in the 2021-2022 school year.

The received data were analyzed calculating the Pearson correlations between ALEKS progress and the state test scores or the difference between the state scores. ALEKS progress was considered to be the independent variable, and state test scores were considered to be the dependent variable. This study is classified as quasi-experimental correlational study of a single group of participants with two variables measured for each participant (Gravetter & Wallnau, 2012).

In the first hypothesis of this study, it was assumed that there was no statistically significant correlation between ALEKS progress and growth in state assessments. ALEKS progress was measured as the percentage of the topics mastered during any given school year after the Initial Knowledge Check was taken in the beginning of the year. For example, after taking the Initial Knowledge Check in August, a student may have 20% of the topics assigned to them at their grade level already mastered based on their prior knowledge. If this student reaches 80% mastery by May, then their ALEKS progress was calculated as 60% for that school year.

More than 95% of the students are required to take state assessments in May every year across the state. All released guides to interpret the results show that scoring scales are designed to be on a continuum for all grade levels. This means that there is one scoring scale but the benchmarks to become Basic, Proficient, and Advanced were higher for eighth grade students than for sixth grade students. Using a scale on a continuum makes it easier to observe students' growth year after year. However, the state assessment program itself changed significantly twice over the course of four school years, prompting the State

Department of Education to create new scoring scales which are significantly different from each other. This created difficulties in directly comparing state test scores across all years. If the scoring scales did not change, simple subtraction of the scores would have shown how much a student grew from one year to the next. Then the analysis would have been conducted to find if that growth was due to instruction, ALEKS, or just the natural growth of a child. Unfortunately, the change in scoring scales made it difficult to analyze the data in this manner, which was initially intended when the researcher decided to study ALEKS. However, discovering the differences in scale scores prompted the researcher to find alternative ways to analyze the data, such as standardizing the scores by converting them into z-scores.

After the scores were standardized within each school year, the growth was calculated by subtracting students' post- and pre-test scores. Then the Pearson calculations were calculated between ALEKS progress and growth. Positive correlations were found for the 2015-2016, 2016-2017, 2017-2018, and 2018-2019 school years, $r(82) = .21$, $p =.06$; $r(71) = .40$, $p < .001$; $r(89) = .19$, $p = .07$; and $r(86) = .07$, $p = 51$, respectively. Of these correlations, only the one for 2016-2017 was found to be statistically significant, $r(71) = .40$, $p < .001$. Also, the scoring scales for the May 2016 and May 2017 tests were the same. This meant that there was no need to convert the scale scores to z-scores for 2016-2017. For this reason, correlation was also calculated for this year without using z-scores, and statistically significant positive correlation was found, $r(71) = .37$, $p < .001$.

Scale scores were the same in May 2018 and May 2019. This allowed calculation of the correlation between ALEKS progress and growth without converting the scale scores to z-scores for the 2018-2019 school year as well. The correlation was positive but not statistically significant, r(86) = .17, p = .11. The correlation coefficient was also the lowest for 2018-2019 out of all four years.

The correlation coefficients that were found without converting the scale scores to z-scores in 2016-2017 and 2018-2019 are the most relevant to the purpose of the first hypothesis. Being able to calculate the growth in state test results using scoring scales that are on a continuum was one of the main reasons the researcher decided to study ALEKS. For this reason, the correlations found in 2016-2017 and 2018-2019 are particularly meaningful for the purpose of this study.

In the second hypothesis of this study, it was assumed that ALEKS does not increase students' likelihood of scoring at the higher achievement level on a state test. Similar to the first hypothesis, ALEKS progress throughout each year was selected to analyze the effect of ALEKS. The results of a state assessment at the end of each academic year were selected to analyze the effects of ALEKS. Pearson correlations between ALEKS progress and state test performance in each year were all statistically significant and positive. The highest correlation was in the 2016-2017 school year, r(71) = .54, p < .001. Additionally, there was a significant difference in mean ALEKS progress between the students who scored at Below Basic/Basic and Proficient/Advanced levels ($t_{104.897} = 5.416$, $p < .001$). This means that the students who progressed more on ALEKS during the year are more likely to score at higher achievement levels.

Discussion

Is there a correlation between students' progress on ALEKS and their performance on standardized tests, before and after the implementation of ALEKS, at the middle school level?

The analysis shows that when the state test scores are standardized and combined for all years, there is a statistically significant correlation between ALEKS progress and growth on state assessments, $r(334) = .20, p < .001$. However, when the data are analyzed separately, especially for the 2016-2017 and 2018-2019 school years using scoring scales that were on a continuum, the analysis produced mixed but more meaningful results for the purpose of this study. The correlation in the 2016-2017 school year was found to be positive and statistically significant, $r(71) = .37, p < .001$). The correlation in 2018-2019 was positive but not statistically significant, $r(86) = .17, p < .001$). Such a contradiction makes it difficult to confidently say if progressing more on ALEKS will result in growth in state test scores.

Does a higher completion percentage on ALEKS increase the probability of scoring Proficient or Advanced on a state test?

Significant positive correlations between ALEKS progress and state test performance show that it is more likely for students who progressed more on ALEKS during the year to score at Proficient and Advanced levels. Students scored at these achievement levels also have higher average ALEKS progress than their peers who scored at Below Basic and Basic.

Conclusion

The purpose of this quasi-experimental, correlational study was to identify the nature of the relationship between ALEKS and state assessments. The results of analysis show that both ALEKS progress and state test growth, as well as ALEKS progress and state test performance, are positively correlated. However, in terms of statistical significance, the results regarding growth are mixed. This makes it difficult to conclude that progress on ALEKS will result in improved state test scores compared to the previous year. Statistically significant correlation of the combined data suggests that there is some evidence that

ALEKS may improve state test scores. However, more research is needed to be able to say this conclusively. since improvement in state test scores is one of the top reasons ALEKS is being adopted in the mathematics classrooms nationwide.

On the other hand, ALEKS progress is positively and significantly correlated with the state test performance that is taken at the end of each year. Since correlation does not mean causation, this finding should be discussed with caution. Higher ALEKS progress may also be the reason for higher performance on the state assessment. However, it is also possible that the students who are progressing more on ALEKS are already mostly higher performing students, and they would have scored Proficient or Advanced regardless of ALEKS.

The findings show that ALEKS progress may explain state test performance to a certain degree, but this needs to be explored further. If this is valid, it may mean that integrating ALEKS in the mathematics curriculum is worth the expenditure of time, effort, and resources that implementation requires. To be able to say this conclusively, further research with a rigorous experimental design is needed. Suggestions for such further research and other implications of the findings are discussed below.

Implications

The role of technology in education has become increasingly important in the last two decades. This role has expanded from being used mainly for operational tasks to curriculum and then to instruction in more recent years, especially during the COVID-19 pandemic. Arguments for and against the use of technology in the classrooms to increase student learning and concerns regarding its effectiveness have always existed. One of the main and relatively commonly accepted criticisms among educators over the years has been that the technological tools exist only to support the instruction in the classrooms, and they are just another resource for learners and cannot, should not, and will never be able to replace teachers (Carrillo, 2012; Collinson, 2001). This could have been true to a certain degree in the pre-pandemic era, but educators, students, parents, learners, and learning communities in general around the world discovered the facets of educational technology and the new ways it could accommodate learning that were unknown and even beyond imagination prior to the pandemic (Roy et al., 2020). Overnight, many schools around the world became fully dependent on the online educational platforms that claimed to offer and provide engaging curriculum, differentiated and personalized instruction, rigorous assessment, etc.

Several online learning platforms were developed within months, and the existing ones were forced to make improvements to be able to meet the sudden extreme increase in demand and compete in the marketplace. In a sense, educational technology replaced teachers and schools for months. The ways this replacement affected student learning during the pandemic remains to be studied in the upcoming years. Initial reports are not promising, especially for economically disadvantaged populations (Streich et al., 2021). However, the COVID-19 pandemic might have shown the world a glimpse of the future of the education and given educators an idea about the direction it is headed (Kara, 2021).

Most schools are back in in-person sessions and many COVID-19 mandates are being lifted. On one hand, schools are returning to their pre-pandemic normal settings. On the other hand, schools are facing significant changes and new challenges. For example, in the district where this study was conducted, fewer than five out of 1,500 students had requested virtual instruction in the last decade. All of these requests were denied because the district academic committee decided virtual instruction was not in the best interest of the students in those cases. In just the 2021-2022 school year, although the district returned to fully in-person instruction, the number of requests to receive virtual instruction was close to 100. This created a great challenge for the district as it tried to accommodate the needs of these students. Eliminating virtual instruction or denying the requests is not an option for the district anymore, because the students may easily choose to go to another school that offers virtual instruction. This would mean a significant loss of funding for the district. For this reason, the district is forced to accommodate the needs of the students who request virtual instruction. The picture is similar in most schools around the nation.

In-person instruction has become more digitalized as well. Online platforms are being utilized more than ever because they are perceived to provide a differentiated and personalized learning experience more easily than a single teacher could. Posting all student assignments on a platform such as Google Classroom has become a standard expectation, which was not the case in the pre-pandemic era. School leaders are now facing a variety of options of educational technology to be implemented in the classrooms. The option of not choosing is not even on the table anymore (Zalaznick, 2021).

Academic research was already struggling to keep up with the fast pace of educational technology development pre-pandemic. The pace accelerated significantly in the last two years along with the increase in the variety of digital tools. The way academic research reacts to this change will be more apparent in the upcoming years. At this point, more digitalization of learning in schools seems inevitable. This will, most probably, lead to an increased need for more rigorous evaluation of educational technology to provide some guidance to school leaders when they are deciding which digital platform to choose to create a more accessible and equitable learning environment for their students. As a school leader, one of the main concerns of the researcher is the possibility of an increased gap between academic research and educational technology to the point where academic research may lose its relevance in evaluating educational technology. For this reason, one of the implications of this research is to contribute to the body of literature in this area to prevent an acceleration of the widening of this gap.

School leaders should not be solely relying on marketing materials and studies that are funded and promoted by the companies themselves. Independent research studies like this one should provide additional guidance for the decision makers. Informed decision making is important to reduce the amount of time, effort, and financial resources that may otherwise be wasted.

The results of this study will not only assist the school leaders in deciding what educational technology to adopt but also how to implement the adopted digital tools. Varying correlations that were found and presented in Chapter 4 in each school year could be due the varying styles of implementation. Adopting an educational technology like ALEKS involves more pieces such as teacher training, reliable infrastructure, data tracking and analysis, and staff and student buy-in. Sometimes small tweaks in the implementation structure may lead to different results. These variables must be taken into consideration when measuring the effectiveness and deciding to continue the implementation of any educational technology.

Limitations

This is a quasi-experimental study, which means that by definition it cannot find causality between ALEKS progress and state assessment performance. The significant correlations that were found may well be high performing motivated students progressing more on ALEKS and scoring high on state assessments and vice versa. One of the main reasons school leaders adopt ALEKS is to improve students' state test performance, and that is why it was selected as the independent variable of this study. A true experimental study with control and treatment groups needs to conducted to identify the effect of ALEKS on student performance.

The researcher had a positive experience with ALEKS when he was a classroom teacher several years ago. This could be the main bias of the researcher, but being away from the classroom for a long enough time is a control for this bias to a certain degree. In-person conversations with other mathematics teachers over the years who used ALEKS in different years created a sense that not all teachers have similar positive experiences. Some teachers do not like using ALEKS at all, and the others are just neutral and only using it because it is mandated by the district. Being aware of the existence of various experiences is also a control for the personal bias of the researcher.

This research study included samples from only grades six through eight. For this reason, the results of this study can be generalized only to students in these grade levels. The study is also limited to students with low socioeconomic status and may not be generalized to groups of students that are significantly different from this group. More than 90% of the participants were either Black or Latinx. To be able to generalize the findings to other demographic groups, the study needed to include more students from other racial and ethnic backgrounds.

Another limitation of this study is the way ALEKS was implemented at this school. Push by administration regarding ALEKS use was more aggressive in the initial years of adoption. Teacher resistance was high as well. Balance was found over the years, and currently it is expected that students use ALEKS every day during the second half of the 90-minute long mathematics classes. This appears to be a settled culture of mathematics classrooms in the district. However, the archived data that was analyzed in this study were from the years that the implementation, teacher buy-in, and student attitudes were not necessarily the same.

Recommendations for Future Research

To further this research, I would like to create an experimental design where the students are randomly assigned to the control and treatment groups. I would also like to assign the same teacher to both groups to control for the quality of instruction in the classroom. This would be a highly effective teacher with the proven results in the past to make sure that the students who are in the control group are not being treated unfairly. The teacher would also need to have a positive attitude towards ALEKS and capable of motivating students in the treatment group to progress on ALEKS as much as possible within the given time frame. Differences between the average performance on the post-test and growth from pre-test to post-test would reveal more clearly how ALEKS affects student performance. Ideally, the pre-test and post-test are the state assessments because as mentioned above, one of the main goals in adopting ALEKS is to raise the test scores.

I would also like to conduct a longitudinal study comparing the students who had multiple years of ALEKS with those who only had it for one year. As mentioned in Chapter 4, data received from the district for this study most likely included such students. However, the way the students were labeled when the data were received made it impossible to follow each student's progress over multiple years. Additionally, labeling multiple year ALEKS students in these data may raise ethical issues in terms of identifying individual students due to a lower sample size. For these reason, longitudinal analysis was not part of this research.

However, it is important to analyze the effects of ALEKS through various perspectives. Conducting an experimental and a longitudinal study would clarify the nature of the relationship between ALEKS and student performance even further. My goal is to conduct these studies and combine them in an article that shows the progression.

This study can also be expanded to include students from other grade levels as well as racial and ethnic backgrounds, socioeconomic statuses, etc. Suburban and rural schools that use ALEKS need to be identified for such study. One of the main recommendations for the future research is to create designs to measure how much ALEKS is capable of expanding students' mathematics knowledge. Such research would give the mathematics educators a clearer idea regarding if it is worth using ALEKS.

Concluding Thoughts

This study attempted to bring clarity to the relationship between one of the most popular mathematics software programs, ALEKS, and student performance. As education and educational practices change and evolve over time, it is important to stay informed to understand the direction they are going. The COVID-19 pandemic accelerated the evolution of education and opened doors to the possibilities that were unknown before. The world, especially students, experienced a real-life demonstration of how learning was not limited to the walls of a classroom and may occur independently outside of the schools. This powerful experience increased the demand for virtual learning platforms. However, not all of these platforms benefit student learning, and because there are so many, it is impossible to measure the effects of every single one of them. On the other hand, the need to measure their effectiveness has never been greater. To meet this need, more focus should be given to study the effects of educational technology. Otherwise, schools may inevitably turn into organizations that follow the never-ending next popular trend, or continue using unproven and old-school educational technology. To prevent either of these, educators and researchers must focus on finding innovative ways to measure the effectiveness of educational technology and stay up to date on current trends.

REFERENCES

Adams, C. J. (2015, September 9). SAT-ACT performance for 2015 graduates called "disappointing." *Education Week*.

ALEKS Corporation. (2012a). *ALEKS implementation success stories.* https://www.aleks.com/k12/K12-1626_Implementation_Success_Stories.pdf

ALEKS Corporation. (2012b). *What makes ALEKS unique.* https://silo.tips/download/what-makes-aleks-unique

ALEKS Corporation. (2015). *ALEKS placement, preparation and learning.* https://www.aleks.com/highered/math/ALEKS_PPL_Case_Study_Brochure.pdf

Anderson, J. D. (1988). *The education of Blacks in the South, 1860–1935*. University of North Carolina Press.

Anderson, R. E., & Dexter, S. (2005). School technology leadership: An empirical investigation of prevalence and effect. *Educational Administration Quarterly*, *41*(1), 49–82.

Andronie, M., & Andronie, M. (2014). Information and Communication Technologies (ICT) used for education and training. *Contemporary Readings in Law and Social Justice*, *6*(1), 378–386.

Appel, M., & Kronberger, N. (2012). Stereotypes and the achievement gap: Stereotype threat prior to test taking. *Educational Psychology Review*, *24*(4), 609–635.

Arnold, K. D., Lu, E. C., & Armstrong, K. J. (2012). The ecology of college readiness. *ASHE Higher Education Report, 38*(5).

Au, W. (2016). Meritocracy 2.0: High-stakes, standardized testing as a racial project of neoliberal multiculturalism. *Educational Policy*, *30*(1), 39–62.

Ballard, K., & Bates, A. (2008). Making a connection between student achievement, teacher accountability, and quality classroom instruction. *The Qualitative Report*, *13*(4), 560.

Beaton, A. E., Rogers, A. M., Gonzalez, E., Hanly, M. B., Kolstad, A., Rust, K. F., Sikali, E., Stokes, L., & Jia, Y. (2011). *The NAEP primer* (NCES 2011-463). U.S. Department of Education, National Center for Education Statistics.

Bidwell, J. K., & Clason, R. G. (1970). *Readings in the history of mathematics education*. National Council of Teachers of Mathematics.

Blömeke, S., Olsen, R. V., & Suhl, U. (2016). Relation of student achievement to the quality of their teachers and instructional quality. *Teacher Quality, Instructional Quality and Student Outcomes*, *2*, 21–50.

Blyth, E., & Milner, J. (1993). Exclusion from school: A first step in exclusion from society. *Children & Society*, *7*(3), 255–268.

Bohrnstedt, G., Kitmitto, S., Ogut, B., Sherman, D., & Chan, D. (2015). *School composition and the black–white achievement gap* (NCES 2015-018). U.S. Department of Education, National Center for Education Statistics. http://nces.ed.gov/pubsearch

Boyd, D. J., Grossman, P. L., Lankford, H., Loeb, S., & Wyckoff, J. (2009). Teacher preparation and student achievement. *Educational Evaluation and Policy Analysis*, *31*(4), 416–440.

Boyle, E. (2004*). The feminization of teaching in America.* Louis Kampf Writing Prize Essay. Massachusetts Institute of Technology. https://static1.squarespace.com/static/571136450442627fff34d2f5/t/5988af33a803bbf89aea5913/1502129971611/2004Boyle.pdf

Brooks, E. (1880). *Philosophy of arithmetic.* Normal Publishing Company.

Brooks, E. (1883). *Mental science and methods of mental culture: Designed for the use of normal schools, academies, and private students preparing to be teachers*. Normal Publishing Company.

Brooks, W. (2006). Reading representations of themselves: Urban youth use culture and African American textual features to develop literary understandings. *Reading Research Quarterly*, *41*(3), 372–392.

Brow, M. V. (2018). Significant predictors of mathematical literacy for top-tiered countries/economies, Canada, and the United States on PISA 2012: Case for the sparse regression model. *British Journal of Educational Psychology*, *89*(4), 726–749.

Byun, S., Irvin, M., & Bell, B. (2015) Advanced math course taking: Effects on math achievement and college enrollment. *The Journal of Experimental Education*, *83*(4), 439–468.

Campbell, J. R., Hombo, C. M., & Mazzeo, J. (2000). *NAEP 1999 trends in academic progress: Three decades of student performance.* U.S. Department of Education.

Canfield, W. (2001). ALEKS: A web-based intelligent tutoring system. *Mathematics and Computer Education*, *35*(2), 152.

Carpenter, J., & Hanna, R. E. (2006, June). Predicting student preparedness in calculus. In *2006 Annual Conference & Exposition* (pp. 11-1009).

Carrillo, F. A. G. (2012). Can technology replace the teacher in the pedagogical relationship with the student? *Procedia - Social and Behavioral Sciences*, *46,* 5646–5655.

Carle, A. C., Jaffee, D., & Miller, D. (2009). Engaging college science students and changing academic achievement with technology: A quasi-experimental preliminary investigation. *Computers & Education*, *52*(2), 376–380.

Cartledge, G., Tillman, L., & Talbert-Johnson, C. (2001). Professional ethics within the context of student discipline and diversity. *Teacher Education and Special Education, 24*(1)*,* 25–37.

Charalambous, C. Y., & Hill, H. C. (2012). Teacher knowledge, curriculum materials, and quality of instruction: Unpacking a complex relationship. *Journal of Curriculum Studies*, *44*(4), 443–466.

Cherng, H. (2017). If they think I can: Teacher bias and youth of color expectations and achievement. *Social Science Research*, *66*, 170–186.

Chetty, R., Friedman, J. N., & Rockoff, J. E. (2014). Measuring the impacts of teachers II: Teacher value-added and student outcomes in adulthood. *American Economic Review*, *104*(9), 2633–2679.

Cheung, A. C. K., & Slavin, R. E. (2013). The effectiveness of educational technology applications for enhancing mathematics achievement in K-12 classrooms: A meta-analysis. *Educational Research Review*, *9*, 88–113.

Chudgar, A., Chandra, M., Iyengar, R., & Shanker, R. (2015). School resources and student achievement: Data from rural India. *Prospects*, *45*(4), 515–531.

Colburn, W. (1821). *Arithmetic on the plan of Pestalozzi.* Cummings & Hilliard.

Collinson, V. (2001). Intellectual, Social, and Moral Development: Why Technology Cannot Replace Teachers. *The High School Journal*, *85*(1), 35–44.

Conley, D. T., Drummond, K. V., De Gonzalez, A., Rooseboom, J., & Stout, O. (2011). *Reaching the goal: The applicability and importance of the common core state standards to college and career readiness.* Educational Policy Improvement Center. https://www.academia.edu/11616224/Lining_Up_The_Relationship_between_the_Common_Core_State_Standards_and_Five_Sets_of_Comparison_Standards

Corman, B. R. (1957). The effect of varying amounts and kinds of information as guidance in problem solving. *Psychological Monographs: General and Applied*, *71*(2), 1–21. https://doi-org/10.1037/h0093696

Courville, K. (2011). *Educational technology: Effective leadership and current initiatives.* Louisiana Computer Using Educator's Conference.

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 students' knowledge and behaviors. *Computers & Education*, *68*, 495–504.

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Sage.

Darling-Hammond, L. (1991). The implications of testing policy for quality and equality. *The Phi Delta Kappan*, *73*(3), 220–225.

Davidson, L. Y. J., Richardson, M., & Jones, D. (2014). Teachers' perspective on using technology as an instructional tool. *Research in Higher Education Journal, 24.*

Davies, C. (1851). *The logic and utility of mathematics: With the best methods of instruction explained and illustrated*. Barnes & Company.

Davis, S., Darling-Hammond. L., LaPointe, M., & Meyerson, D. (2005). *School leadership study: Developing successful principals*. Stanford Educational Leadership Institute.

de Chiusole, D., Stefanutti, L., Anselmi, P., & Robusto, E. (2015). Modeling missing data in knowledge space theory. *Psychological Methods, 20*(4), 506–522.

Delpit, L. D. (1992). Education in a multicultural society: Our future's greatest challenge. *The Journal of Negro Education, 61*(3), 237. https://doi-org.proxy.library.umkc.edu/10.2307/2295245

Diamond, J. B., & Posey-Maddox, L. (2020). The changing terrain of the suburbs: Examining race, class, and place in suburban schools and communities. *Equity & Excellence in Education 2020, 53*(1–2, 7–13). https://www.tandfonline.com/doi/pdf/10.1080/10665684.2020.1758975

Doignon, J.-P., Falmagne, J.-C., Johannesen, L., Koppen, M. & Villano, M. (1990). Introduction to knowledge spaces: How to build test and search them. *Psychological Review*, *97*, 201–224.

Donham, J. (2014). College Ready—What can we learn from first-year college assignments? An examination of assignments in Iowa colleges and universities. *School Library Research*, *17*, 1–21.

Enomoto, E. K., & Conley, S. (2007). Harnessing technology for school accountability: A case study of implementing a management information system. *Planning and Changing*, *38*, 164–180.

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.

Etim, J. S., Etim, A. S., & Blizard, Z. D. (2020). Teacher effects, student school attendance and student outcomes: Comparing low and high performing schools in North Carolina. *Educational Research Quarterly*, *44*(2), 48–84.

Every Student Succeeds Act (ESSA). (2017). U.S. Department of Education. https://www.ed.gov/essa?src=rn/

Falmagne, J., Cosyn, E., Doble, C., Thiery, N., & Uzun, H. (2007). Assessing mathematical knowledge in a learning space: Validity and/or reliability. *Annual Meeting of the American Educational Research Association (AERA)*.

Falmagne, J. C., Cosyn, E., Doignon, J. P., & Thiéry, N. (2006). The assessment of knowledge, in theory and in practice. In B. Ganther, G. Stumme, & R. Wille (Eds.), *Formal concept analysis* (pp. 61–79). Springer.

Falmagne, J. C., Koppen, M., Villano, M., Doignon, J.-P., & Johannesen, L. (1990). Introduction to knowledge spaces: How to build, test, and search them. *Psychological Review*, *97*(2), 201–224. https://doi-org.proxy.library.umkc.edu/10.1037/0033-295X.97.2.201

Ferguson, M. (2020). Washington view: What the NAEP reveals. *Phi Delta Kappan*, *101*(5), 62–63. https://doi-org.proxy.library.umkc.edu/10.1177/0031721720903832

Ferraro, S. (2018). Is information and communication technology satisfying educational needs at school? *Computers & Education*, *122*, 194–204. https://doi-org.proxy.library.umkc.edu/10.1016/j.compedu.2018.04.002

Flores, A. (2007). Examining disparities in mathematics education: Achievement gap or opportunity gap? *High School Journal, 91*(1), 29–42.

Flores, O. J., & Gunzenhauser, M. G. (2021). Justice in the gaps: School leader dispositions and the use of data to address the opportunity gap. *Urban Education*, *56*(2), 261–288.

Fryer, R. G., Jr., & Levitt, S. D. (2004). Understanding the Black-White test score gap in the first two years of school. *Review of Economics and Statistics*, *86*, 447–464.

Fullan, M. (2004). *Leadership & sustainability: System thinkers in action* Corwin Press.

Fullan, M. (2006). *Change theory: A force for school improvement.* Centre for Strategic Education Seminar Series Paper, No. 157.

Fullan, M. (2001). *Leading in a culture of change.* Jossey-Bass.

Furr, J. (1996). *A brief history of mathematics education in America* [Unpublished manuscript]. College of Education, University of Georgia. http://jwilson.coe.uga.edu/EMAT7050/HistoryWeggener. html

Ginsburg, A. L., Noell, J., & Plisko, V.W. (1988). Lessons from the wall chart. *Educational Evaluation and Policy Analysis*, *70*(1), 1–12.

Goddard, Y. L., Goddard, R. D., Bailes, L. P., & Nichols, R. (2019). From school leadership to differentiated instruction: A pathway to student learning in schools. *Elementary School Journal*, *120*(2), 197–219.

Goldhaber D., Quince, V., & Roddy, T. (2019). Teacher quality gaps in U.S. public schools: Trends, sources, and implications. *The Phi Delta Kappan*, *100*(8), 14–19.

Goldsmith, P. A. (2004). Schools' racial mix, students' optimism, and the Black-White and Latino-White achievement gaps. *Sociology of Education*, *77*, 121–147.

Gravetter, F. J., & Wallnau, L. B. (2012). *Statistics for behavioral sciences* (10th ed.) Cengage.

Grumet, M. (1988). *Bitter milk: Women and teaching.* University of Massachusetts Press.

Gutiérrez, R. (2008). A "Gap-gazing" fetish in mathematics education? Problematizing research on the achievement gap. *Journal for Research in Mathematics Education, 39*(4), 357–364.

Gutiérrez, R., & Dixon-Román, E. (2011). Beyond gap gazing: How can thinking about education comprehensively help us (re)envision mathematics education? In B. Atweh, M. Graven, W. Secada, & P. Valero (Eds.), *Mapping equity & quality in mathematics education* (pp. 21–34). Springer.

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

Hallinger, P., & Heck, R. H. (1996). Reassessing the principal's role in school effectiveness: A review of the empirical research, 1980-1995. *Educational Administration Quarterly, 32*, 5–44.

Hampikian, J., Gardner, J., Moll, A., Pyke, P., & Schrader, C. (2006). *Integrated pre-freshman engineering and pre-calculus mathematics.* American Society for Engineering Education.

Hampikian, J., Guarino, J., Chyung, S. Y., Gardner, J., Moll, A., Pyke, P., & Schrader, C. (2007). Benefits of a tutorial mathematics program for engineering students enrolled in pre-calculus: A template for assessment. *American Society for Engineering Education*, *12*(305), 1–11.

Handal, B., & Herrington, A. (2003). Re-examining categories of computer-based learning in mathematics education. *Contemporary Issues in Technology and Teacher Education*, *3*(3), 275–287.

Hansot, E., & Tyack, D. B. (1982). *Managers of virtue: Public school leadership in America, 1820–1980*. Basic Books.

Hanushek, E. A., Peterson, P. E., Talpey, L. M., & Woessmann, L. (2019). *The unwavering SES achievement gap: Trends in U.S. student performance* (No. w25648). National Bureau of Economic Research.

Hanushek, E. A., & Rivkin, S. G. (2007). Pay, working conditions, and teacher quality. *Future of Children*, *17*(1), 69–86.

Hanushek, E. A., & Rivkin, S. G. (2009). Harming the best: How schools affect the black-white achievement gap. *Journal of Policy Analysis and Management*, *28*(3), 366–393. https://doi-org.proxy.library.umkc.edu/10.1002/pam.20437

Hill, H. C., Blunk, M. L., Charalambous, C. Y., Lewis, J. M., Phelps, G. C., Sleep, L., & Ball, D. L. (2008). Mathematical knowledge for teaching and the mathematical quality of instruction: An exploratory study. *Cognition and Instruction*, *26*(4), 430–511.

Hook, W., Bishop, W., & Hook, J. (2007). A quality math curriculum in support of effective teaching for elementary schools. *Educational Studies in Mathematics*, *65*(2), 125–148. doi:10.1007/s10649-006-9050-4

Hu, X., Luellen, J. K., Okwumabua, T. M., Xu, Y., & Mo, L. (2008). *Observational findings from a web-based intelligent tutoring system: Elimination of racial disparities in an undergraduate behavioral statistics course.* http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.518.9582

Hung, M., Smith, W. A., Voss, M. W., Franklin, J. D., Gu, Y., & Bounsanga, J. (2020). Exploring student achievement gaps in school districts across the United States. *Education & Urban Society*, *52*(2), 175.

Irizarry, Y. (2015). Selling students short: Racial differences in teachers' evaluations of high, average, and low performing students. *Social Science Research*, *52*(5), 522–538.

Jackson, C.K. (2018). What do test scores miss? The importance of teacher effects on non-test score outcomes. *Journal of Political Economy*, *126*(5), 2072–2107.

Jacob, B. A. (2007). The challenges of staffing urban schools with effective teachers. *Future of Children*, *17*(1), 129–153.

Johnson, A. D. (2016). Principal perceptions of the effectiveness of university educational leadership preparation and professional learning. *International Journal of Educational Leadership Preparation*, *11*(1).

Jones, K., Wilson, R., Clark, L., & Dunham, M. (2018). Poverty and parent marital status influences on student achievement. *Educational Research Quarterly*, *42*(1), 62–80.

Joseph, R. (2009). Closing the achievement gap with culturally relevant technology-based learning environments. *Educational Technology*, 45–47.

Kara, A. (2021). COVID-19 pandemic and possible trends for the future of higher education: A review. *Journal of Education and Educational Development*, *8*(1), 9–26.

King, M. R. N., Rothberg, S. J., Dawson, R. J., & Batmaz, F. (2016). Bridging the edtech evidence gap: A realist evaluation framework refined for complex technology initiatives. *Journal of Systems and Information Technology*, *18*(1), 18–40.

Kinney, L. B., & Tulock, M. K. (1957). Mathematics in the secondary schools. *Review of Educational Research*, *27*(4), 356.

Kirschner, P. A., & Erkens, G. (2006). Cognitive tools and mindtools for collaborative learning. *Journal of Educational Computing Research*, *35*(2), 199–209.

Klein, D. (2003). A brief history of American K-12 mathematics education in the 20th century. *Mathematical Cognition*, 175–225.

Koenig, J. A., & Edley, C. F. (2017). *Evaluation of the achievement levels for mathematics and reading on the National Assessment of Educational Progress*. National Academies Press.

Kolb, L. (2019). Smart classroom-tech integration. *Educational Leadership, 76*(5), 20–26.

Koppen, M. & Doignon, J.-P. (1990). How to build a knowledge space by querying an expert? *Journal of Mathematical Psychology*, *34*, 311–331.

Ladson-Billings, G. (2006). From the achievement gap to the education debt: Understanding achievement in U.S. schools. *Educational Researcher*, *35*(7), 3–12.

Ladson-Billings, G., Welner, K. G., & Carter, P. L. (2013). *Closing the opportunity gap: What America must do to give every child an even chance.* Oxford University Press.

LaFerrara, M. A. (2013). The conflict over standardized testing is a consequence of government-run schools. *The Objective Standard, 8*(2), 78.

Lambert, L., Walker, D., Zimmerman, D. P., Cooper, E. J., Lambert, M. D., Gardner, M.E., & Szabo, *M.* (2002). *The constructivist leader.* Teachers College Press.

LaVergne, V. (2007). *The effect of the ALEKS web-based learning system on standardized math scores.* Unpublished action research project in Shawnee Mission Schools.

Shawnee, KS.
https://www.aleks.com/k12/Shawnee_Mission_Board_of_Education.pdf

Lavigne, A. L. (2020). Examining individual- and school-level predictors of principal adaptation to teacher evaluation reform in the United States: A two-year perspective. *Educational Management Administration & Leadership*, *48*(2), 379–395.

Lee, J. (2002). Racial and ethnic achievement gap trends: Reversing the progress toward equity? *Educational Researcher*, *31*(1), 3–12.

Lee, J., & Reeves, T. (2012). Revisiting the impact of NCLB high-stakes school accountability, capacity, and resources: State NAEP 1990-2009 reading and math achievement gaps and trends. *Educational Evaluation and Policy Analysis*, *34*(2), 209–231.

Lehnen, R. G. (1992). Constructing state education performance indicators from ACT and SAT scores. *Policy Studies Journal*, *20*(1), 22–40.

Leithwood, K., Louis, K. S., Anderson, S., & Wahlstrom, K. (2004). *How leadership influences student learning.* The Wallace Foundation. Available at www.wallacefoundation.org/knowledge-center/school-leadership/key-research/Pages/How-Leadership-Influences-Student-Learning.aspx

Leithwood, K., Patten, S., & Jantzi, D. (2010). Testing a conception of how school leadership influences student learning. *Educational Administration Quarterly*, *46*(5), 671–706.

Li, Q., & Ma, X. (2010). A meta-analysis of the effects of computer technology on school students' mathematics learning. *Educational Psychology Review*, *22*(3), 215–243.

Lim, C.-P., Zhao, Y., Tondeur, J., Chai, C.-S., & Tsai, C.-C. (2013). Bridging the gap: Technology trends and use of technology in schools. *Educational Technology & Society*, *16*(2), 59–68.

Linn, R. L. (2001). A century of standardized testing: Controversies and pendulum swings. *Educational Assessment, 7*(1), 29–38.

Long, M., Conger, D., & Iatarola, P. (2012). Effects of high school course-taking on secondary and postsecondary success. *American Educational Research Journal*, *49*(2), 285–322.

Louis, K.S., Leithwood, K., Wahlstrom, K., & Anderson, S. (2010). *Investigating the links to improved student learning: Final report of research findings.* The Wallace Foundation. Available at www.wallacefoundation.org/knowledge-center/school-leadership/key-research/Pages/Investigating-the-Links-to-Improved-Student-Learning.aspx.

Loveless, T., & Diperna, P. (2000). *The Brown Center report on American education: How well are American students learning?* https://www.brookings.edu/research/2015-brown-center-report-on-american-education-how-well-are-american-students-learning/

Lowther, D. L., Inan, F. A., Daniel Strahl, J., & Ross, S. M. (2008). Does technology integration “work” when key barriers are removed? *Educational Media International*, *45*(3), 195–213.

Lynch, J. M. (2012). Responsibilities of today’s principal: Implications for principal preparation programs and principal certification policies. *Rural Special Education Quarterly*, *31*(2), 40–47.

Lytras, M., & Pouloudi, A. (2001). E-learning: Just a waste of time. *AMCIS 2001 Proceedings,* 43. https://aisel.aisnet.org/cgi/viewcontent.cgi?article=1482&context=amcis2001

Madigan, J. C. (2009). The education of women and girls in the United States: A historical perspective. *Advances in Gender and Education, 1*(1), 11.

Mark, M. M., & Reichardt, C. S. (2004). Quasi-experimental and correlational designs: Methods for the real world when random assignment isn't feasible. In C. Sansone, C. C. Morf, & A. T. Panter (Eds.), *The SAGE handbook of methods in social psychology* (pp. 265–286). Sage.

Martinez, M. A., Lewis, K., & Marquez, J. (2020). College ready at a cost: Underrepresented students overwhelmed, scared, increasingly stressed, and coping. *Education and Urban Society*, *52*(5), 734–758.

Marzano, R. J., & Waters, T. (2009). *District leadership that works: Striking the right balance*. Solution Tree Press.

Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Cambridge University Press.

Meece, J. L., Anderman, E. M., & Anderman, L. H. (2006). Classroom goal structure, student motivation, and academic achievement. *Annual Review of Psychology*, *57*(1), 487–503.

Mendoza-Denton, R. (2014). A social psychological perspective on the achievement gap in standardized test performance between white and minority students: Implications for assessment. *The Journal of Negro Education*, *83*(4), 465–484.

Milner IV, H. R. (2012). Beyond a test score: Explaining opportunity gaps in educational practice. *Journal of Black Studies*, *43*(6), 693–718.

Missouri Department of Elementary and Secondary Education. (2019). *English Language Arts and Mathematics Grade 3-8 and Science Grades 5 and 8 technical report 2019.* Data Recognition Corporation.

Murphy, C. J. (2018). *Role of the principal in implementing blended learning in Algebra I courses in South Carolina public schools* [Doctoral dissertation, University of South Carolina]. ProQuest Information & Learning. https://scholarcommons.sc.edu/etd/4184

National Center for Education Statistics. (2019). *2019 NAEP mathematics and reading assessments: Highlighted results at grades 4 and 8 for the nation, states, and districts*. National Center for Education Statistics, Institute of Education Sciences, U.S. Dept. of Education.

National Commission on Excellence in Education. (1983). A nation at risk: The imperative for educational reform. *The Elementary School Journal*, *84*(2), 113–130.

National Council of Teachers of Mathematics. (1980). *An agenda for action: Recommendations for school mathematics of the 1980s.* National Council of Teachers of Mathematics.

No Child Left Behind Act of 2001, P.L. 107-110, 20 U.S.C. § 6319 (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]. Georgia State University. http://scholarworks.gsu.edu/msit_diss/94

Oakes, J., Ormseth, T., Bell, R. M., & Camp, P. (1990). *Multiplying inequalities: The effects of race, social class, and tracking on opportunities to learn mathematics and science.* Rand Corporation. https://www.rand.org/pubs/reports/R3928.html

Orfield, G., Frankenberg, E. D., & Lee, C. (2002). The resurgence of school segregation. *Educational Leadership*, *60*(4), 16.

Overview of ALEKS. (n.d). McGraw Hill ALEKS. https://www.aleks.com/about_aleks/overview

Page, M. S. (2002). Technology-enriched classrooms: Effects on students of low socioeconomic status. *Journal of Research on Technology in Education*, *34*(4), 389.

Pannell, S., & Sergi-McBrayer, J. (2020). An examination of the impact of educational leadership field experience structure on instructional leadership preparedness. *International Journal of Educational Leadership Preparation*, *15*(1), 92–106.

Poffenberger T., & Norton, D. A. (1956). Factors determining attitudes toward arithmetic and mathematics. *The Arithmetic Teacher*, *3*(3), 113–116.

Powell, M. A., Fitzgerald, R., Taylor, N. J., & Graham, A. (2012, March). *International literature review: Ethical issues in undertaking research with children and young people* (Literature review for the Childwatch International Research Network). Lismore: Southern Cross University, Centre for Children and Young People / Dunedin: University of Otago, Centre for Research on Children and Families.

Powell, B., & Steelman, L. C. (1984). Variations in state SAT performance: Meaningful or misleading? *Harvard Educational Review*, *54*(4), 389–412.

Ready, D. D., & Wright, D. L. (2011). Accuracy and inaccuracy in teachers' perceptions of young children's cognitive abilities: The role of child background and classroom context. *American Educational Research Journal*, *48*(2), 335–360.

Reardon, S. F. (2013). The widening income achievement gap. *Educational Leadership*, *70*(8), 10–16.

Rebarber, T. (2020). *The Common Core debacle: Results from 2019 NAEP and other sources*. White Paper No. 205. Pioneer Institute for Public Policy Research.

Reeves, T. C., & Oh, E. G. (2017). The goals and methods of educational technology research over a quarter century (1989–2014). *Educational Technology Research and Development, 65,* 325–339.

Reitzug, U. (1994). Diversity, power and influence: Multiple perspectives on the ethics of school leadership. *Journal of School Leadership, 4*(2), 197–222.

Riegle-Crumb, C. & Grodsky, E. (2010). Racial-ethnic difference at the intersection of math course-taking and achievement. *Sociology of Education, 83*(3), 248–270.

Rivkin, S. G., Hanushek, E. A., & Kain, J. F. (2005). Teachers, schools, and academic achievement. *Econometrica*, *73*(2), 417–458.

Ronfeldt, M., Loeb, S., & Wyckoff, J. (2013). How teacher turnover harms student achievement. *American Educational Research Journal*, *50*(1), 4–36.

Ross, S. M. (2020). Technology infusion in K-12 classrooms: A retrospective look at three decades of challenges and advancements in research and practice. *Educational Technology Research and Development*. https://doi-org.proxy.library.umkc.edu/10.1007/s11423-020-09756-7

Ross, S., Smith, L., Morrison, G., & Erickson, A. (1989). An apple a day and at night: A distance tutoring program for at-risk students. *Educational Technology*, *29*(8), 23–28.

Roy, N., Karsenti, T., Poellhuber, B., & Parent, S. (2020). The impact of COVID-19 on Higher Education and Educational Technology – Part 2. Learning during the pandemic: The student experience and new ways of teaching. *Revue Internationale Des Technologies En Pédagogie Universitaire*, *17*(3), 4–6.

Schrum, L. R., & Levin, B. B. (2015). *Leading 21st century schools: Harnessing technology for engagement and achievement.* Sage.

Seeley, L., & Grube, A. W. (1888). *Grubé's method of teaching arithmetic.* EL Kellog & Company.

Sergiovanni, T. J., & Starratt, R. J. (2007). *Supervision: A redefinition* (8th ed.). McGraw-Hill.

Silva, C. M., Moses, R. P., Rivers, J., & Johnson, P. (1990). The Algebra Project: Making middle school mathematics count. *The Journal of Negro Education*, *59*(3), 375–391.

Silvernail, D. L., & Gritter, A. K. (2007). *Maine's middle school laptop program: Creating better writers.* Maine Education Policy Research Institute, University of Southern Maine.

Silvernail, D. L., & Lane, D. (2004). The impact of Maine's one-to-one laptop program on middle school teachers and students. *Education Technology, 13.*

Silvernail, D. L., Pinkham, C. A., Wintle, S. E., Walker, L. C., & Bartlett, C. L. (2011). *A middle school one-to-one laptop program: The Maine experience*. Maine Education Policy Research Institute, University of Southern Maine.

Smith, D. (2013). ALEKS: An artificial intelligence-based distance learning system. *Distance Learning*, *10*(3), 51.

Spector, J. M. (2020). Remarks on progress in educational technology. *Educational Technology Research & Development, 68*(3), 833–836. https://doi-org.proxy.library.umkc.edu/10.1007/s11423-020-09736-x

Spring, J. (1997). *Deculturalization and the struggle for equality: A brief history of the education of dominated cultures in the United States*. McGraw-Hill.

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.

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

Streich, F., Pan, J., Ye, C., & Xia, J. (2021). *Estimating changes to student learning in Illinois following extended school building closures due to the COVID-19 pandemic.* REL 2022-131. Regional Educational Laboratory Midwest.

Supovitz, J., Sirinides, P., & May, H. (2010). How principals and peers influence teaching and learning. *Educational Administration Quarterly*, *46*(1), 31–56. https://doi-org.proxy.library.umkc.edu/10.1177/1094670509353043

Talbert-Johnson, C. (2004). Structural inequities and the achievement gap in urban schools. *Education and Urban Society*, *37*(1), 22–36.

Taylor, J. (2008, Fall). 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*, *39*(1).

Taylor, V. J., & Walton, G. M. (2011). Stereotype threat undermines academic learning. *Personality and Social Psychology Bulletin, 37*(8), 1055–1067.

Texas Center for Educational Research. (2008). *Evaluation of the Texas technology immersion pilot: Outcomes for the third year (2006–07).* Report prepared for the Texas Education Agency, Austin, TX.

Thomas, L. G., & Knezek, D. (1991). Providing technology leadership for restructured schools. *Journal of Research on Computing in Education*, *24*(2), 265–279.

Thorndike, E. L. (1906). An empirical study of college entrance examinations. *Science, 23*(596), 839–845.

Vanneman, A., Hamilton, L., Anderson, J. B., & Rahman, T. (2009). *Achievement gaps: How black and white students in public schools perform in mathematics and reading on the national assessment of educational progress. Statistical Analysis Report.* NCES 2009-455. National Center for Education Statistics.

Waters, T., McNulty, B. A., Marzano, R. J. (2005). *School leadership that works: From research to results*. Association for Supervision & Curriculum Development.

Wightman, L. F. (2003). Standardized testing and equal access: A tutorial. In M. J. Chang, D. Witt, J. Jones, & K. Hakuta (Eds.), *A compelling interest: Examining the evidence on racial dynamics in colleges and universities*, 49–96. Stanford University Press.

Willoughby, S.S. (1967). *Contemporary teaching of secondary school mathematics.* Wiley & Sons.

Woodson, C. G. (2006). *The mis-education of the Negro*. Book Tree.

Xu, J., Meyer, K., & Morgan, D. (2009). A mixed-methods assessment of using an online commercial tutoring system to teach introductory statistics. *Journal of Statistics Education*, *17*(2).

Yilmaz, B., & Caruthers, L. E. (2017). *Effects of adaptive learning technologies on math achievement: A quantitative study of ALEKS math software.* Semantics Scholar. https://www.semanticscholar.org/paper/Effects-of-Adaptive-Learning-Technologies-on-Math-A-Yilmaz/2938a7477f06d7a72f1e3be4ff5efe78548eef58

Zalaznick, M. (2021). Remote learning post-pandemic: How districts are continuing to offer virtual instruction even as most schools return in person. *District Administration*, *57*(8), 23–25.

VITA

Elyar Isgandarli was born on June 27, 1988 in Baku, Azerbaijan. He graduated from a private high school in Baku and was admitted to Azerbaijan State Oil and Industry University in Baku, Azerbaijan. Upon completing his undergraduate studies in drilling engineering there, Elyar moved to the United States to pursue graduate studies. He started teaching middle school computer science in Houston, Texas. Elyar taught computer science and mathematics for two years in Houston and moved to Kansas City, Missouri in 2011. There he taught mathematics and robotics for another year and became an assistant principal/college counselor in 2012. Elyar earned his master's degree in educational leadership from University of Missouri-Kansas City while working as a school administrator.

After working at Frontier School of Excellence for seven years as a teacher and assistant principal, Elyar was promoted to a principal position at the same school. He led the school successfully for three years and was transferred to another school with the highest enrollment in the same district. Currently, Elyar continues to serve as a principal at Frontier School of Innovation-Middle School.