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Relationships Between High School Students' Performance in ALEKS Placement, Preparation, and Learning (PPL) Modules and Performance on the ALEKS College Mathematics Placement Exam

Jenny V. Nehring
Utah State University

RELATIONSHIPS BETWEEN HIGH SCHOOL STUDENTS' PERFORMANCE IN ALEKS PLACEMENT, PREPARATION, AND LEARNING (PPL) MODULES AND PERFORMANCE ON THE ALEKS COLLEGE MATHEMATICS PLACEMENT EXAM

by

Jenny V. Nehring

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Approved:

Patricia Moyer-Packenham, Ph.D. Major Professor	Sylvia Read, Ph.D. Committee Member
Jessica Shumway, Ph.D. Committee Member	Kady Schneiter, Ph.D. Committee Member
Katherine Vela, Ph.D. Committee Member	D. Richard Cutler, Ph.D. Interim Vice Provost for Graduate Studies

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ABSTRACT

Relationships Between High School Students' Performance in ALEKS Placement, Preparation, and Learning (PPL) Modules and Performance on the ALEKS College Mathematics Placement Exam

by

Jenny V. Nehring, Doctor of Philosophy

Utah State University, 2021

Major Professor: Patricia Moyer-Packenham, Ph.D.
Department: School of Teacher Education and Leadership

The misalignment between the mathematics taught in high school and the mathematics expected at colleges and universities has created a difficult transition for high school students in the U.S. from high school to college level mathematics. Intelligent Tutoring Systems (ITS) have been used to help high school students transition from the mathematics taught in high school to the mathematics expected at colleges and universities across the country. The purpose of this study was to examine relationships between high school students' performance in Assessment and LEarning in Knowledge Spaces (ALEKS) Placement, Preparation, and Learning (PPL) Modules and performance on the ALEKS College Mathematics Placement Exam.

This study used a quasi-experimental nonequivalent research design. The participants in this study were 100 students, from five high schools in a single school district. Students were in two groups: the ALEKS Group, who completed the ALEKS PreCalculus Learning Modules, and the Non-ALEKS Group, who did not complete the modules. The analysis included a 2x2 mixed ANOVA to measure how assignment of the modules affected exam scores. A logistic regression was used to assess differences between the two groups in placing into college algebra. A multiple linear regression was used to identify factors that influenced growth on the ALEKS Mathematics Placement Exam.

There was a statistically significant difference in exam scores between the ALEKS Group and the Non-ALEKS Group which indicated that assignment to the ALEKS PPL PreCalculus Learning Modules did increase performance on the ALEKS College Mathematics Placement Exam. Conversely, assignment to the ALEKS PPL PreCalculus Modules did not increase students' likelihood of placing into College Algebra.

The factors that influenced student outcomes on the ALEKS Mathematics Placement exam for those students assigned to the ALEKS Group included the amount of time spent taking the exam in May and the number of modules mastered. These results show that schools could implement ITS into their current mathematics classrooms and help students increase their scores on the ALEKS Mathematics Placement Exam, which has the potential to decrease the number of remedial courses students need to take in college.

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PUBLIC ABSTRACT

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DEDICATION

This dissertation is dedicated to my husband, Mat, who has loved me unconditionally throughout my doctoral studies. He has encouraged and supported me even when I thought I could not continue any longer. Without him, I would not be the person I am today, and I am forever grateful for his love, support, and the sacrifices that he makes for me. In addition, I would like to dedicate this work to my two young children, Sophia and Daniel, who patiently allowed me to work on my studies over the years. Finally, to my son, Jaron, who I lost in the middle of this journey. I know he would be proud of this accomplishment and for me not giving up during the most difficult time of my life, losing my boy. I love you all.

Jenny V. Nehring

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CHAPTER I

INTRODUCTION

Statement of the Problem

High school students in the U.S. often face a difficult transition from the mathematics taught in high school to the mathematics expected at colleges and universities across the country. One of the most significant contributing factors to this problem is the misalignment between high school mathematics and college-level mathematics (Barnett, Fay, Bork, & Weiss, 2013; Madison et al., 2015; Venezia, Kirst, & Antonio, 2003). College algebra is often referred to as one of the mathematics gatekeeper courses because it is a required foundational course needed to earn numerous degrees in colleges and universities (Hilgoe, Brinkley, Hattingh, & Bernhardt, 2016; Rech & Harrington, 2000). Research has shown that this misalignment is related to three main issues. First, high school students are not being prepared for college-level mathematics which is a cause of the misalignment. This has resulted because high school mathematics standards are different from college mathematics standards. Because of that difference in standards, high school mathematics assessments require different knowledge and skills than do college entrance and placement exams (Barnett, Fay, Trimble, & Pheatt, 2013; Bettinger, Boatman, & Long, 2013; Hilgoe et al.; Venezia et al., 2003). This lack of preparedness results in approximately half of the students entering college being required to enroll in remedial courses (Venezia et al., 2003). Second, many students are unaware of their deficiencies and so they do not make any additional preparations for college-level mathematics, which causes further misalignment (Hilgoe et al., 2016; Strong American Schools, 2008; Venezia et al., 2003). When students lack awareness, this causes cognitive dissonance about why they are required to take remedial courses when they successfully finished higher-level mathematics courses in high school (Venezia et al., 2003). Third, when students are required to take remedial mathematics courses in college as a result of the misalignment, there are negative consequences. One of the consequences is a lower probability that students will complete their college degree (Bahr, 2013; Bailey, 2009; Hilgoe et al., 2016; Mejia, Rodriguez, & Johnson, 2016; National Center for Public Policy and Higher Education & Southern Regional Education Board [NCPPHE & SREB], 2010; Ngo & Kwon, 2015). Another consequence is higher student debt (Strong American Schools, 2008) and spending more time in college (Bahr, 2013; Mejia et al., 2016). This may lead to students giving up on their dream of obtaining a college degree, which leads to earning significantly less money in their careers over their lifetime (Bettinger et al., 2013; Venezia et al., 2003). Because of the misalignment between high school mathematics and college-level mathematics, there is a higher probability that students will take remedial courses and fall further behind.

Background of the Problem

Many educational institutions have attempted to address the problem of high school mathematics not being aligned with college-level mathematics. Several states have increased their high school graduation requirements to try to increase college readiness for mathematics (Barnett, Fay, Bork, & Weiss, 2013; Madison et al., 2015; Venezia et al., 2003). Even though states, such as California, have implemented policies requiring high school courses to have college readiness standards that are linked to first-year coursework in mathematics and English, two-thirds of the students that enter California State University have to take remediation courses (NCPPHE & SREB, 2010). Similar results have occurred in other states throughout the country. Research shows that students who take remediation courses are generally good students with a GPA of 3.0 or higher in high school (NCPPHE & SREB, 2010; Strong American Schools, 2008). This shows that research is needed to find more effective ways to address the problem of reaching better alignment between high school and college-level mathematics.

Many states have tried to help students become more aware of their mathematical deficiencies by creating testing policies (Ewell, Boeke, & Zis, 2008; Hilgoe et al., 2016; Kurlaender, 2014). These policies include creating an early mathematics placement exam at the state level or letting students take university placement exams during their sophomore and junior year to determine who needs remediation. Some schools use the results of the placement exam to motivate students to take a mathematics course their senior year of high school (Ewell et al., 2008; Hilgoe et al., 2016; Kurlaender, 2014). These state policies have had positive effects, such as an increase in students who take mathematics coursework their senior year and therefore increase their chances of being ready for college-level mathematics (Fine, Duggan, & Braddy, 2009; Hilgoe et al., 2016; Hoyt & Sorenson, 2001). Even with the addition of these state policies, many students are still graduating high school unprepared for college-level mathematics.

The use of remedial mathematics courses to address the problem of graduating from high school unprepared for college-level mathematics tackles one problem but creates many other consequences. To address the problem of the overuse of remedial mathematics courses, several colleges have implemented the use of multiple measures in an attempt to increase the number of students who have access to higher-level mathematics (Ngo & Kwon, 2015). Using more than one measure to determine college-level mathematics placement, such as the use of high school GPA, previous mathematics courses taken, and multiple placement exams, is a better predictor of college-level mathematics readiness (Madison, et al., 2015; Ngo & Kwon, 2015). Despite all of these policies, many students are graduating from high school underprepared for college-level mathematics.

Purpose of the Study

The purpose of this study was to examine relationships between high school students' performance in Assessment and LEarning in Knowledge Spaces (ALEKS) Placement, Preparation, and Learning (PPL) Modules and performance on the ALEKS College Mathematics Placement Exam. Because of the misalignment between the mathematics preparation students receive in high school and their readiness for college-level mathematics (Conley, 2003), Intelligent Tutoring Systems (ITS), such as the ALEKS PPL program, have been created by educational companies and are used ubiquitously in the secondary school setting (Oxman & Wong, 2014). Government grants provided to many universities funded initial efforts to design ITS to mimic one-on-one tutoring for public K-12 schools (Oxman & Wong, 2014). Each learner's psychological state is modeled by the ITS to provide individualized instruction and adaptive remediation (Ma, Adesope, Nesbit, & Liu, 2014). The development of the ALEKS PPL intelligent tutoring program was the result of one of these government grants and provides each student individualized mathematics practice to prepare students for college-level mathematics (McGraw-Hill Education, 2020c). ITS has the potential to play an important role in addressing the problem of the misalignment between high school mathematics and college-level mathematics for many students.

Research Questions

Three main research questions guided this study.

1. How does assignment to the ALEKS PPL PreCalculus Learning Modules affect growth over time on the ALEKS PPL Mathematics Placement Exam?
2. What is the difference between the Non-ALEKS PPL Group and the ALEKS PPL Group in the percentage of students who score high enough to place into College Algebra, according to the ALEKS PPL Mathematics Placement Exam?
3. What factors (module time, module mastery scores, teacher, exam score) influence student outcomes on the ALEKS PPL Mathematics Placement Exam for those assigned to work on the modules?

Significance of the Problem

Because College Algebra is often a mathematics gatekeeper course that influences students graduating from high school not prepared for college-level mathematics, this can have significant consequences (Hilgoe et al., 2016; Jenkins, Jaggars, & Roksa, 2009). Some of these consequences include decreased college graduation rates, extra classes taken in college, extra tuition payments, and diminished self-confidence (Bettinger et al., 2013; Fine et al., 2009; Hilgoe et al., 2016; Hoyt & Sorenson, 2001; Madison et al., 2015; NCPPHE & SREB, 2010; Ngo & Kwon, 2015; Strong American Schools, 2008; Venezia et al., 2003). When there are decreased college graduation rates and fewer students obtain a college degree, students have fewer opportunities and limited career choices (Venezia et al., 2003). When there are extra classes taken in college, students spend more time in school. This is a problem because it can decrease students' chances of obtaining a college degree (Bettinger et al., 2013; Venezia et al., 2003). The problem with extra tuition payments is that students and taxpayers shoulder this burden, which costs billions of dollars (Bettinger et al., 2013; Hilgoe et al., 2016). Many students are discouraged and perceive diminished self-confidence due to being placed in remedial mathematics courses, which can cause decreased academic momentum and feelings of frustration, anger, and embarrassment (Strong American Schools, 2008). All of these consequences demonstrate that misalignment between high school mathematics and college-level mathematics is a significant problem. For the reasons stated above, it is extremely important to determine how to prepare high school students for college-level mathematics. This study examined the ALEKS PPL as a supplement to regular instruction in senior-level high school mathematics classrooms as a potential way to reduce some of the misalignment between high school and college-level mathematics.

ALEKS PPL is an Intelligent Tutoring System (ITS) that individualizes learning by assessing each student's knowledge state and creating a personalized course of study based on each student's performance with previous concepts (ALEKS, 2018b). ALEKS is the first ITS to incorporate Knowledge Space Theory for assessment and teaching and determines what each student knows, and it offers material that the student is ready to learn (Advanced Customer Solutions, ALEKS Corporation, 2017). ITS programs, like ALEKS PPL, have great potential to supplement mathematics learning in K-12 classrooms by increasing students' mathematics knowledge through individualized learning. These individual mathematics experiences, with targeted mathematics practice, can impact a student's placement in college mathematics courses. Research has shown that technology can have a positive impact on student learning in mathematics (Craig et al., 2013). Several studies have shown the effectiveness of using ITS in mathematics classrooms to improve student readiness for college mathematics (Craig, et al., 2013; Fine et al., 2009; Haulk, Powers, & Segalla, 2015; Sabo, Atkinson, Barrus, Joseph, & Perez, 2013). There is a need for this type of research because of the lack of studies that compare the use of an ITS to comparable classrooms that do not use an ITS for a full academic year. Therefore, this study was designed to examine relationships between high school students' performance in the ALEKS PPL Modules and their subsequent performance on the ALEKS College Mathematics Placement Exam. Examining factors that may support or inhibit students' mathematics development, including the amount of time students spend using the modules or the time students spend engaging with the exam, provides important insights about the potential of the ALEKS PPL to contribute to college mathematics preparation.

Summary of Research Study Design

This study used a quasi-experimental design to determine how the use of ALEKS

(PPL) Modules by high school students relates to the students' performance on the ALEKS PPL Mathematics Placement Exam. The set of data that was used for this study was collected by the researcher during one full academic year under an approved IRB Protocol (#9350, see Appendix B). The researcher's dissertation committee approved the use of this existing data set on May 8, 2019. The existing data set consisted of two groups: The ALEKS PPL Group and the Non-ALEKS PPL Group. Classes in the ALEKS PPL Group participated in regular mathematics class sessions supplemented with ALEKS PPL Modules. Classes in the Non-ALEKS PPL Group participated in regular mathematics class sessions and did not use ALEKS PPL Modules. Both groups completed the ALEKS PPL Mathematics Placement Exam at the beginning and end of the academic school year.

The participants were 100 high school students, ages 16-18 who were enrolled in nine different class sections of College Prep Mathematics during their senior year of high school. The ALEKS PPL Group had 73 participants from three different high schools and the Non-ALEKS PPL Group had 27 participants from two different high schools. The quantitative data sources and measurements that will be used for this study include: ALEKS PPL Mathematics Placement Exam Scores from October and May, ALEKS PPL PreCalculus Learning Module Mastery Scores for the ALEKS PPL Group, and ALEKS PPL Time Data. The data will be analyzed using a 2x2 mixed Analysis of Variance (ANOVA), logistic regression, and multiple linear regression, along with descriptive statistics.

Definition of Terms

The following terms are defined for this study.

ALEKS PPL: Assessment and LEarning in Knowledge Spaces (ALEKS), Placement, Preparation, and Learning (PPL) is technology developed by mathematicians, cognitive scientists, and software engineers with the help of a large multi-million-dollar grant from the National Science Foundation. ALEKS PPL is based on Knowledge Space Theory and uses artificial intelligence to map the details of each student's knowledge state (ALEKS, 2018b)

ITS: Intelligent Tutoring Systems are adaptable computer programs that provide individualized instruction by modeling individual students' psychological states and adjust to fit the specific needs and characteristics of each student (Ma et al., 2014).

Mathematics practice: The event of instruction provided to students after they have been given information essential to master an objective and involves evoking performance from the students (Martin, Klein, & Sullivan, 2007).

Remedial courses: Courses offered that are below college-level and usually are not degree-applicable or transferable. These courses provide instruction in foundation skills in mathematics which are necessary for students to succeed in college-level mathematics (Mejia et al., 2016).

CHAPTER II

LITERATURE REVIEW

Introduction/Purpose

The purpose of this study was to examine relationships between high school students' performance in ALEKS PPL Modules and performance on the ALEKS College Mathematics Placement Exam. Commercial product developers have devoted a great deal of time to developing ITS that can offer remediation for those wanting to learn/relearn mathematics concepts. ITS are computer programs that are often self-paced, learner-led, and very adaptable. Their adaptability comes from being able to adjust to fit the specific needs and characteristics of the learner by providing individualized instruction (Ma et al., 2014; Steenbergen-Hu & Cooper, 2013). Although there is no replacement for a teacher in the classroom, and simply incorporating technology into the classroom does not increase performance significantly, there are ways that ITS can improve student readiness for college mathematics (Craig et al., 2013; Fine et al., 2009; Sabo et al., 2013; Haulk et al., 2015). Therefore, looking at different ways that ITS can increase college readiness should be explored.

The first part of this chapter presents the conceptual framework for this study. Next, three main areas of the literature are explored to support this framework. The first area examines the misalignment between high school mathematics preparation and readiness for college-level mathematics. The second area describes the development of ITS, and the promise of programs like the ALEKS PPL to individualize mathematics learning. The third area discusses Drijvers' organization of technologies for mathematics learning and the role of practice in learning mathematics. These three areas support the framework and guide the development of the current research project.

Conceptual Framework

The conceptual framework for this study was based on three primary premises (see Figure 1). The first premise was that there is a misalignment between the high school mathematics preparation students receive and their readiness for college-level mathematics needed for success. In the figure, this is shown by the arrow pointing from high school mathematics at the bottom of the figure while college mathematics is located at the upper right corner of the figure. This represents the large gap between high school and college mathematics. The second premise was that ITS, like the ALEKS PPL

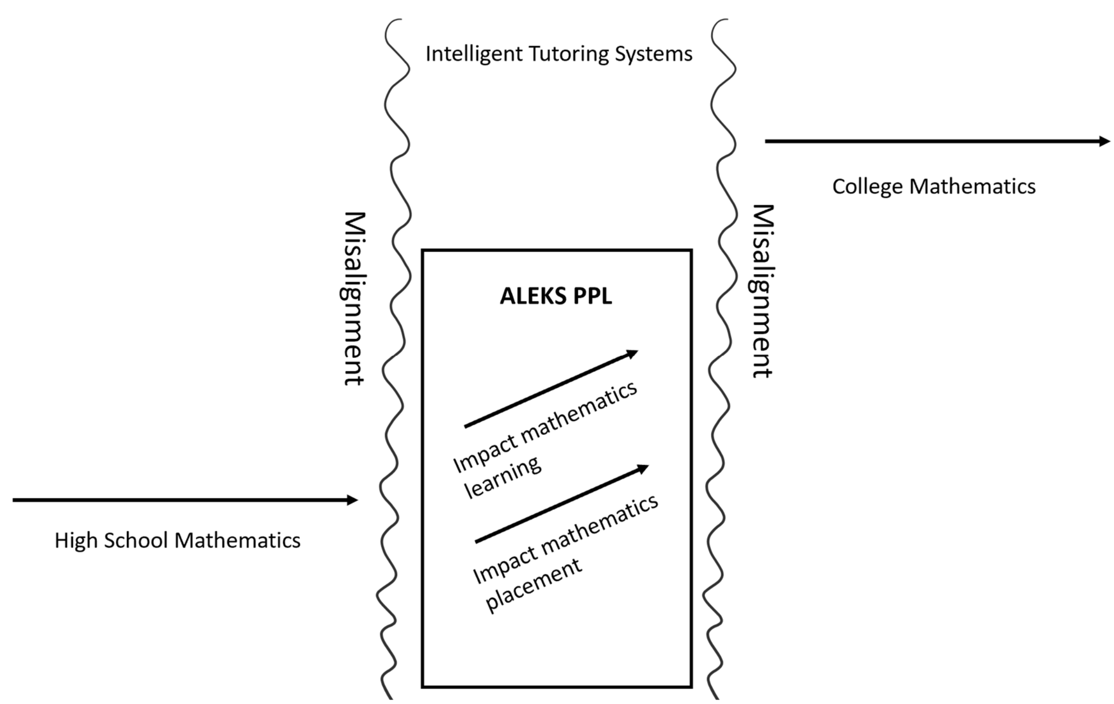

Figure 1. Conceptual framework.

program, emerged because there was a misalignment in mathematics between high school and college. Programs like the ALEKS PPL hold promise for supplementing mathematics learning in K-12 classrooms, enhancing students' experiences to create better alignment, and impacting placement in college mathematics courses because they individualize learning. In the figure, this is shown by the space between the wavy lines where the ALEKS PPL program is placed. This shows the potential of the ALEKS PPL to impact mathematics learning for high school students to better prepare them for college mathematics. The third premise was that programs like the ALEKS PPL provide opportunities for individualized mathematics practice, a core element of Drijvers, Tabach and Vale's (2018) role of digital technology with mathematics. In the figure, this is shown by the arrows located inside the ALEKS PPL box that point upwards towards college mathematics. These arrows show the impact that using the ALEKS PPL for practice may have on mathematics learning and mathematics placement. Opportunities for practice can raise students' mathematical knowledge to the level needed for them to place into appropriate college mathematics courses. The review of the literature in this chapter is organized according to these three big ideas.

The Misalignment Between High School Math and College Math

One of the most arduous transitions in American education is the transition from high school mathematics to college mathematics. Notably, the main reason is the disconnect between the mathematics taught in high school and a similar college course (Barnett et al., Fay, Bork, & Weiss, 2013; Madison, et al., 2015; Venezia et al., 2003).

This section discusses how high schools are not preparing students for college-level mathematics, students are not aware of their mathematics deficiencies, and remedial courses are the result of the misalignment between high school mathematics courses and college mathematics.

High Schools are Not Preparing Students for College Math

There is a misalignment between high school mathematics preparation and readiness for college-level mathematics. Even though education in America has come a long way over the last century, too many students are graduating from high school unprepared for college-level coursework (Barnett, Fay, Trimble, & Pheatt, 2013; Bettinger et al., 2013; Hilgoe et al., 2016). These numbers vary across the country, but roughly 60% of all students entering college will need to take remedial courses (Bailey, 2009; Barnett, Fay, Trimble, & Pheatt, 2013; NCPPHE & SREB, 2010). For example, California has policies that high school students have college readiness standards that are linked to first-year coursework in mathematics and English. However, 68% of the 50,000 students entering California State University (CSU) required remediation in either mathematics, English, or both, during their freshman year. This is despite a system-wide policy that requires students to have a high school grade-point average of at least a B and have taken a college-preparatory curriculum while in high school (NCPPHE & SREB, 2010). The numbers are far worse at the community colleges in California where over 80% of incoming freshmen need remedial coursework (Ngo & Melguizo, 2016). California is home to about 20% of all community colleges in the country.

Clearly, earning a high school diploma does not mean that students are ready to succeed in college, or even be able to register for college-level classes, as indicated by the high rates of remedial placement in college. Yet, these students have passed the "high stakes" testing required for graduation. According to the NCPPHE and SREB (2010), there are several reasons for the gap in knowledge that exists between what students learn in high school and what is expected in college. One of the reasons includes:

> Most states that have high school exit exams or other "high-stakes" tests readily acknowledge that the exams measure proficiency at the 8th- to 10th-grade levels. They are set at this level due to pressures on states and schools to minimize the numbers of students who do not receive a diploma. (NCPPHE & SREB, 2010, p. 3)

Another reason is that high school classes are not rigorous enough and teachers' demands on students are not adequate (Strong American Schools, 2008). For example, Strong American Schools reported that the majority of students who were required to take remediation classes in college were assumed to be good students in high school and that approximately four out of five students reported a high school GPA of 3.0 or higher. This research demonstrates that over half of high school graduates with good grades (e.g., GPA = 3.0) are not prepared for college-level mathematics.

Over the last several years many states have raised high school graduation requirements to increase the college readiness of their high school graduates, however, many students are still not prepared (Barnett, Fay, Bork, & Weiss, 2013; Madison et al., 2015; Venezia et al., 2003). There is a lack of rigor and consistency in grading (Strong American Schools, 2008), and a misunderstanding of what students are expected to know to be prepared for college-level mathematics (Hilgoe et al., 2016; Strong American

Schools, 2008; Venezia et al., 2003). Because of this disconnect, curriculum developers have created ITS like the ALEKS PPL Modules to provide supplemental mathematics instruction that is intended to fill in gaps in students' mathematics learning.

This disconnect between the mathematics taught in high school and a similar college course is due in part to the influence of reform efforts to cover a broader range of content in the high school, while college mathematics places more emphasis on paper-and-pencil manipulative algebraic skills (Madison et al., 2015). Teachers in elementary and secondary schools teach mathematics mainly focused on their own state standards and curriculum assessments (NCPPHE & SREB, 2010). Besides, without a national accord about what mathematics skill level constitutes college-readiness or a consensus about how to assess that level, it is a challenge for K-12 educators to meet such criteria. For instance, during 1992, there were 125 combinations of 75 different placement exams administered at colleges and universities in the southeastern U.S. alone (Venezia et al., 2003). Even if different colleges used the same exam, they may have different cutoff scores for placement into courses. This makes it difficult for high schools and students to know what level of knowledge is needed for college readiness (Barnett, Fay, Bork, & Weiss, 2013). The report by Venezia et al. (2003) explains:

> State K-12 standards have swept across the country with scant participation by postsecondary education institutions or systems. Postsecondary admissions and placement officials overwhelmingly reported that they were unaware of K-12 standards and assessments, and K-12 educators were usually unaware of specific postsecondary admission and placement policies. Postsecondary education respondents stressed that K-12 policies are politically volatile and may change quickly; therefore, they were wary about using data from K-12 assessments because they did not want to become tethered to tumultuous, and politicized exams. (p. 22)

High school and college educators need to work together to create consistent placement policies for graduating high school seniors. Doing so will help high schools develop curricula to better prepare students for college-level mathematics.

Students Unaware of their Mathematics Deficiencies

Many students are unaware of their mathematics deficiencies and presume that if they graduate from high school, they are ready for college-level mathematics (Hilgoe et al., 2016; Strong American Schools, 2008; Venezia et al., 2003). Despite all the literature that supports the findings that students are not prepared for college-level mathematics, many high school students presume that, if they complete the required courses needed for graduation, they will be prepared for college-level mathematics. Hence, students are unaware of their deficiencies until they take a college placement exam.

Completing upper-level mathematics courses in high school, such as calculus, does not guarantee college readiness because many of these students end up taking remedial courses or repeating courses already taken in high school (Bettinger et al., 2013; Rueda & Sokolowski, 2004). Therefore, the time to take a college placement exam is sooner rather than later so that students can become aware of their mathematics deficiencies. The report by ACT's Forgotten Middle claims that "the level of academic achievement that students attain by eighth grade has a larger impact on their college and career readiness by the time they graduate from high school than anything that happens academically in high school" (ACT, 2008, p. 2). This has been refuted by others such as Royster, Gross, and Hochbein (2015), who found that several other factors can impact students' chances of college readiness while in high school, such as college aspirations and college preparatory coursework. Even though students have the opportunity to take mathematics every year in high school, only two thirds of the nation's high school graduates took advantage of this opportunity (Reyes & Domina, 2017). Ideally, taking the college placement exam during the junior year of high school will allow time for students to register for college preparatory remediation classes during their senior year (Barnett, Fay, Bork, & Weiss, 2013; Venezia et al., 2003). Therefore, taking college placement exams allows students to be aware of their deficiencies before registering for college.

Some states have created policies to help students become aware of mathematics deficiencies. The state of North Carolina established the North Carolina Early Mathematics Placement Testing (NC EMPT) program to help reduce the number of incoming freshmen enrolling in remedial mathematics by providing a low stake "reality check" test that measures college-level mathematics readiness. Hilgoe et al. (2016) found that there was a high correlation between students that failed the NC EMPT and enrolled in remedial mathematics. The goal of the NC EMPT is to let students know that they are unprepared before they graduate so that they will have time to remediate before they enter college. The results indicate that the NC EMPT is an accurate early screening tool as well as an effective indicator of the prospect of success in a college mathematics coursework (Hilgoe et al., 2016). This is an example of one effective policy to help students prepare for college-level mathematics.

The California State University system decided it would be better to test students their sophomore year to determine which students need remediation. The students are provided an opportunity to take the University's placement exam, so they can see their current level of readiness and provide plenty of time to allow students to remediate deficiencies (Ewell et al., 2008). Kurlaender (2014) analyzed the data from California's Early Assessment Program (EAP) and found that students who participated in the voluntary program experienced lower rates of remedial coursework at community colleges. The EAP also allows students to take a placement exam in their junior year of high school and lets them know if they are ready for college-level coursework. One of the goals of the EAP is to inform students of their English and mathematics placement at any of California's 23 CSU campuses and hopefully motivate them to take their senior year courses more seriously to better prepare for graduation. Kurlaender analyzed California's 112 community colleges and found that the results were significant for the reduction of English remedial coursework but were inconclusive for the reduction of mathematics remedial coursework. This was partly because in order for students to take the math portion of the EAP, they had to have taken a prerequisite math class. Because of the state policy that allowed students to take the placement exam early, students were better prepared for college-level mathematics.

Furthermore, studies have shown that students can increase their chances of being ready for college-level mathematics upon graduation from high school if they take mathematics their senior year (Fine et al., 2009; Hilgoe et al., 2016; Hoyt & Sorenson, 2001). In addition, Reyes and Domina (2017) found that students are more likely to take optional mathematics classes in high school if they consider themselves good at mathematics, have a high interest level in mathematics, or have high expectations of going to college. Reyes and Domina found that above-track students were those who took four years of mathematics in high school and considered themselves to be good at mathematics or had an interest in mathematics, whereas the rest of the students, those in the on-track or low-track, who took four years of mathematics, did so because of high expectations of attending college. When students take mathematics every year in high school, this can have a positive effect on readiness for college-level mathematics.

To summarize, this research shows that students benefit from taking a college placement exam and also taking four years of mathematics in high school. This is significant because, with the help of policymakers in providing access to college placement exams and teachers/parents encouraging students to take four years of high school mathematics, students can improve the likelihood of college readiness. However, students can benefit even more if high schools and colleges work together to align standards to further college readiness.

Remedial Courses are the Result of Misalignment Between High School Math and College Math

Only 30% of students who enroll in remedial mathematics pass all of their remedial mathematics courses (Attewell, Lavin, Domina, & Levey, 2006). This leads to students taking courses multiple times in order to pass the course, which increases the time and cost of attending college. According to a report from Strong American Schools (2008), for the 2004-2005 school year, there were almost one million students enrolled in remedial classes in public 2-year colleges that cost between $1.9 and $2.4 billion. Furthermore, there were 310,403 students enrolled in remedial courses at public four-year institutions with a cost between $435 and $543 million. These numbers show that this problem is not just a problem for the students who will need remediation, but for our nation as a whole since many of the students who take remedial classes are low-income students who get federal funding, provided by the taxpayer, to pay for these classes (Bailey, Jeong, & Cho, 2010; Goodwin, Li, Broda, Johnson, & Schneider, 2016; Strong American Schools, 2008). Because of this, there should be an urgency to address the situation of high enrollment in remedial courses.

Remedial mathematics courses have been described as “not an entryway but a burial ground for the aspirations of myriad community college students seeking to improve their lives through education” (Bahr, 2013, p. 172). This may seem harsh, but this description does not come without merit. Remediation of incoming college freshman students is a national concern because remediated students are at higher risk of failing to complete their degrees (Bahr, 2013; Bailey, 2009; Hilgoe et al., 2016; NCPPHE & SREB, 2010; Ngo & Kwon, 2015). The national average for students who attend college their first year and need to take remedial courses is 60% (NCPPHE & SREB, 2010), while states such as California have rates as high as 80% which take an average of 2.5 terms for those that need developmental mathematics to complete (Mejia et al., 2016). According to Bahr, the national average of community college students who require remedial mathematics is approximately two thirds while nearly three fourths of those that begin the remedial mathematics sequence are unsuccessful in completing a college-level mathematics course. This shows the importance of making sure that students who are assigned into remediation are truly incapable of passing a college-level course without taking the remedial courses and not misplaced by a placement exam.

The overarching goal of remedial mathematics courses is to prepare students for success in college-level mathematics courses. The achievement of this goal was addressed by Ulmer, Means, Cawthon, and Kristensen (2016). The results indicate performance in MAT 090 was a strong positive predictor of grade in MAT 105. The ultimate problem is that the majority of students referred to take remedial courses fail to complete the course sequence, which traditionally can be anywhere from one to five courses (Bailey et al., 2010). Bahr (2013) found that students who did not complete the remedial mathematics sequence and ultimately did not achieve college-level competency were likely to remain enrolled at the community college for several semesters yet never achieve any credentials. Furthermore, when lower students are placed in the remedial sequence, the lower their chances are of completing college-level mathematics (Ngo & Kwon, 2015; Ngo & Melguizo, 2016; Mejia et al., 2016). Although 44% of remedial mathematics students in California's 113 community colleges complete the course sequence, only 17% of those who are placed four levels below college-level mathematics manage to finish the sequence (Mejia et al., 2016). Finally, the rate of transfer to a four-year institution for students who take remedial classes compared with those who do not is 24% versus 65% (Mejia et al., 2016). Enrolling in remedial courses hinders progress towards degree completion, which is why it is necessary for students to place into college-level mathematics their freshman year.

To summarize, roughly 60% of all students entering college will need to take remedial courses (Bailey, 2009; Barnett, Fay, Bork, & Weiss, 2013; NCPPHE & SREB, 2010). More effort needs to be made to ensure that students graduate from high school prepared for college-level mathematics. Efforts need to focus on informing students of their deficiencies to allow them to register for the appropriate mathematics classes in high school (Barnett, Fay, Bork, & Weiss, 2013; Venezia et al., 2003). The research above points out the implications of taking remedial courses such as low graduation rates and time and cost to students and taxpayers. As a result, every effort should be made to make sure that students are accurately placed in the appropriate mathematics courses to avoid these consequences.

Development of Intelligent Tutoring Systems like the ALEKS PPL Program to Individualize Mathematics Learning

The development of ITS was preceded by the development of Computer Assisted Technology (CAI), which occurred in the 1950s. During the 1980s, ITS started to develop separate from the foundations of CAI and early stipulations for ITS mandated that they should be able to "diagnose errors and tailor remediation based on the diagnosis" (Shute & Psotka, 1994, p. 9). To this day, ITS use the idea of diagnosis and remediation to promote learning. The section below discusses how the ALEKS PPL program individualizes learning and examines several factors that may impact the effects of ITS.

How the ALEKS PPL Program Individualizes Learning

The emergence of ITS in public schools was brought about by government grants

(McGraw-Hill Education, 2020c; Oxman & Wong, 2014). In 1992, a large National Science Foundation (NSF) grant was obtained to develop educational software based on Knowledge Space Theory (McGraw-Hill Education, 2020c). This is where ALEKS began. ITS, like the ALEKS PPL program, hold promise for supplementing mathematics learning in K-12 classrooms because they can individualize learning.

ALEKS is based on the knowledge space theory of Doignon and Flamange (1985), which identifies a field of knowledge as a large, finite set of questions or problems, and the knowledge state of the learner is all the questions that a person can answer about that particular field. Knowledge space is therefore identified as being the network of all possible knowledge states. ALEKS uses this theory by having "students learn components of a set of knowledge within a set of questions, and if they are able to master a set within a knowledge-state, they build upon that and are able to move into the next knowledge state" (Fanusi, 2015, p. 93). ALEKS maps the students' knowledge and is then able to build the ideal path for individual students within the knowledge space (ALEKS, 2018a). ALEKS is an ITS that provides a custom course of study for each student based on the student's success with previous concepts. Students are continuously monitored, and knowledge checks are given periodically to promote retention (Fine et al., 2009). ALEKS PPL applies knowledge space theory to individualize mathematics learning based on the student's prior responses.

Allowing students the opportunity to remediate in high school, by practicing with rigorous problems that universities expect students to know, can save students valuable time and money and lead to high college graduation rates (Fine et al., 2009). Studies have shown that students who attend after-school programs tend to outperform their peers who do not attend after-school programs both in the classroom and on standardized tests (Craig et al., 2013). Craig et al. conducted a study in which students were randomly assigned to either teacher-led classrooms or ALEKS-led classrooms. The purpose of the study was to compare learning from a teacher versus computer-mediated learning from ALEKS in an after-school environment. The measure of performance outcomes for both classrooms was the Tennessee Comprehensive Assessment Program (TCAP). Results for the study showed the ALEKS-led classrooms performed better, although the results were not statistically significant (Craig et al., 2013). The findings are significant because the curriculum for the teacher-led classrooms was created by mathematics education experts and implemented by highly experienced certified teachers using technology such as smart boards. This can be very costly in comparison to the ALEKS-led classrooms where students required much less assistance from teachers (Craig et al., 2013). Another benefit to the ALEKS-led classroom was students did not miss important instruction if they were absent. Haulk et al. (2015) found that web-based homework is just as effective as paper-and-pencil homework, which can free up valuable time for teachers. These examples represent some of the benefits of using ITS, such as ALEKS PPL, in the classroom.

Sabo et al. (2013) evaluated two mathematics intelligent-tutoring systems, ALEKS Algebra Course and Carnegie Learning Algebra Cognitive Tutor, to see if they could reach the two-sigma advantage that human based one-on-one tutoring affords. The study took place during the summer in two high school computer labs; one lab used ALEKS and the other used Carnegie. Students were randomly assigned to either the

ALEKS lab or the Carnegie lab for the 14-day course and worked on their assigned program with a high school mathematics teacher available to answer their algebra questions. The Accuplacer was given as a pre-test on day one, as a repeated measure assessment on day seven, and as a post-test on day 13. The results showed no statistically significant differences between the two tutoring systems on Accuplacer algebra scores over time (Sabo et al., 2013). ALEKS had an effect size of $d = 0.95$ and Carnegie's effect size was $d = 1.18$, which is not close to the $d = 2$ that Bloom (1984) reported with human one-on-one tutoring. The study lacked a control group with a traditional algebra classroom condition and a treatment group with human one-on-one tutors to verify the previous results obtained by Bloom. Without the control group, there was no way to verify the conditions that were most beneficial to algebra students. Despite the limitations, this study shows that intelligent tutoring systems are effective in remediating high school algebra students, which can be meaningful to school districts that do not have highly qualified mathematics teachers.

According to Bloom (1984), human one-on-one tutoring has a two-sigma advantage over traditional classroom instruction (as cited in Sabo et al., 2013, p. 1833). These results have never been duplicated; therefore, the account of Bloom's study led many researchers in the field of ITS to believe the effect size of $d = 2$ to be the standard of adult human tutors compared to traditional classroom instruction (VanLehn, 2011). VanLehn himself found the effect size of human tutoring to be significantly lower than Bloom's at $d = 0.79$, and he also found the effects of ITS to be 0.76. These results are remarkably close to each other, signifying that ITS, such as ALEKS, can be nearly as effective as one-on-one tutoring.

Understanding the need for change, the University of Illinois has a unique placement program based on ALEKS. This program is based on the hypothesis that initial knowledge at the start of a course should be indicative of student achievement in that course (Ahlegren & Harper, 2013). The purpose of the placement program is to reduce unsuccessful student outcomes. ALEKS is the tool used to measure students' knowledge. Every student is required to take an ALEKS assessment placement exam within four months of the start of courses regardless of whether or not they have a passing grade in a prerequisite course. Ahlegren and Harper examined whether an ALEKS assessment is more effective at measuring specific abilities of a student than the ACT, which was the previous measure of success before the incorporation of ALEKS. The results of the study found a strong correlation between course grades and initial student assessment in ALEKS. The correlation found with ALEKS was much stronger than the ACT Math Exam. Many students took the ACT exams four months before the start of the course, which is when students took the ALEKS exams. This could account for the stronger correlation that the ALEKS assessment achieved and could account for the results of Madison et al. (2015), since their participants were all recent high school graduates. Another potential problem with this research is the authors are paid consultants for the implementation of placement programs and Harper is a consultant at ALEKS, creating a potential bias (Ahlegren & Harper, 2013). Future studies should assess students at similar times to avoid these potential confounding factors.

To summarize, ALEKS PPL allows students to remediate in high school while giving students the opportunity to fill in gaps in their mathematics knowledge. Several studies show the effectiveness of using ALEKS to either inform students of their deficiencies or remediate mathematic topics. The following section will discuss some factors that can impact student outcomes of ITS such as ALEKS PPL.

A Variety of Factors May Impact Effects of Intelligent Tutoring Systems

The use of ITS, like the ALEKS PPL program, are only effective when used with fidelity because many factors may influence their effectiveness. Student attitudes, teacher support, and time spent with the technology, all can play a role in student outcomes but unfortunately, there is limited research in this area. Using the technology for the recommended time given by the program designer should be used in the implementation of the program. Ideally, the teacher should be supportive of the technology and encourage the use and recognize students who complete the recommended time and lessons.

The amount of time students spend working with technology can affect student outcomes. Cheung and Slavin (2013) found that educational technology programs were more effective if they required more than 30 minutes per week than those that were used less. ALEKS recommends using the program at least three hours per week for effective implementation, along with clear and formal support of the program (Advanced Customer Solutions, ALEKS Corporation, 2017). Many students did not use the program for the recommended time and used the technology less than 10 minutes per week (Cheung & Slavin, 2013). The lack of time spent by students on the technology is not only an implementation problem but could also be from a lack of support from teachers who do not see the value of the program (Cheung & Slavin, 2013). Without teacher support of the program, students might not use the program effectively and not achieve the desired effects of the program. ALEKS offers many suggestions to support ALEKS PPL in the classroom such as assigning a point value to their final grade for completing the required time spent in ALEKS PPL. Implementation results will vary without teachers consistently using the program with fidelity, making it hard for researchers to conclude the effectiveness of ITS. This shows a need for more research about the fidelity of teacher implementation of ITS programs and time spent working with the ITS.

Role of Practice in Mathematics Learning

Technology can provide tools for students to learn and practice mathematics by providing problems students are ready to learn, provide immediate feedback, and offer help with remediation by affording tutorial resources (Roschelle, Noss, Blikstein, & Jackiw, 2017). The feedback provided by technology increases students' correct responses and decreases the likelihood of subsequent incorrect responses (Martin et al., 2007). ALEKS PPL is designed to provide each student with the problems that they are ready to learn with immediate feedback and keep track of problems that each student most recently learned to reinforce newly learned skills (Advanced Customer Solutions, ALEKS Corporation, 2017). This section discusses Drijvers, Tabach, and Vale's (2018) organization of technologies for mathematics learning and how the ALEKS program promotes individualized practice.

Organization of Technologies for Mathematics Learning

With the growth of technology, researchers began organizing roles of technology in education. Drijvers et al. (2018) modeled a taxonomy of didactical roles of digital technology for mathematics that categorizes roles for digital technology in mathematics education as a tool for outsourcing mathematics, practicing skills, and concept development. Technology as a tool for both practicing skills and concept development reside under the tool for learning mathematics category (see Figure 2). The tool for outsourcing mathematics refers to the use of tools (such as calculators) for offloading low-level or procedural work so that students can concentrate on the core mathematics concepts (Drijvers et al., 2018). There is some overlap between the tool for outsourcing mathematics and the tool for concept development. This can happen when technology supports concept development but some of the math is outsourced to the technology so that students can focus on concept development (Drijvers et al., 2018). These tools provide a framework for doing symbolic and numeric computational work and also contribute significantly to how mathematics is conceptualized (Roschelle et al., 2017).

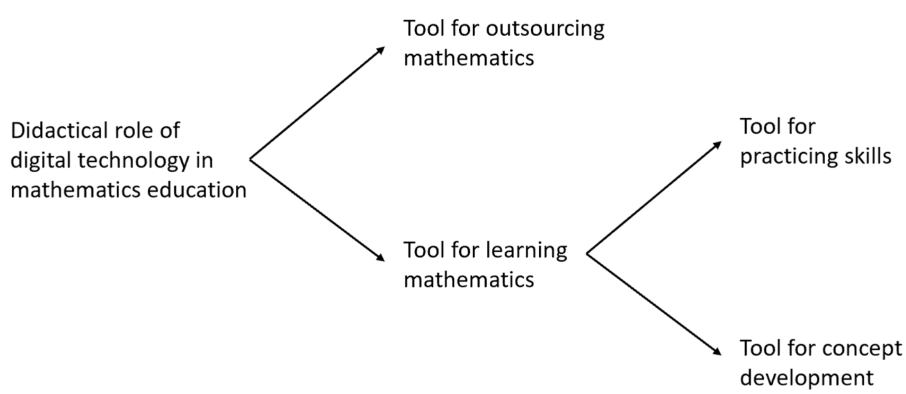

Figure 2. Taxonomy of didactical roles of digital technology for mathematics (Drijvers et al., 2018).

Technology that is designed specifically to teach mathematics fits under both a tool for practicing skills and a tool for concept development. Tools for concept development are more focused on fostering the development of student sense making and understanding and attention to epistemology is often increased (Hoyles, Noss, & Kent, 2004). Conceptual understanding is seen as the connections or relationships between ideas, and technology provides a medium for displaying and observing these relationships (Heid & Blume, 2008). On the other hand, with tools for practicing skills, tools are designed to efficiently organize student practice, provide students with rapid feedback, and can help students find the tutorial resources focused on the problem at hand (Drijvers et al., 2018; Roschelle et al., 2017). Intelligent tutoring systems, such as ALEKS PPL, fit into this category.

There are many ways to organize effective practice of skill and instructional options. Figure 3 shows one such path denoted by the thicker arrows. Principles for how to organize effective practice skills are found in abundance in the cognitive science literature (Drijvers, 2012). One such principle is to space learning over time to increase learning and retention. This can easily be done using technology such as ALEKS PPL because they utilize spacing regimes such as “Knowledge Checks,” which check to make sure previously learned material is still mastered and, if not, then to reintroduce those concepts back into current lessons. ALEKS PPL also uses the blocked practice strategy. Blocked practice refers to grouping mathematics practice problems together that require the use of the same strategy (Rohrer, Dedrick, & Sterschic, 2015). For example, the 246 topics in the ALEKS PreCalculus learning module are grouped by problem type. When

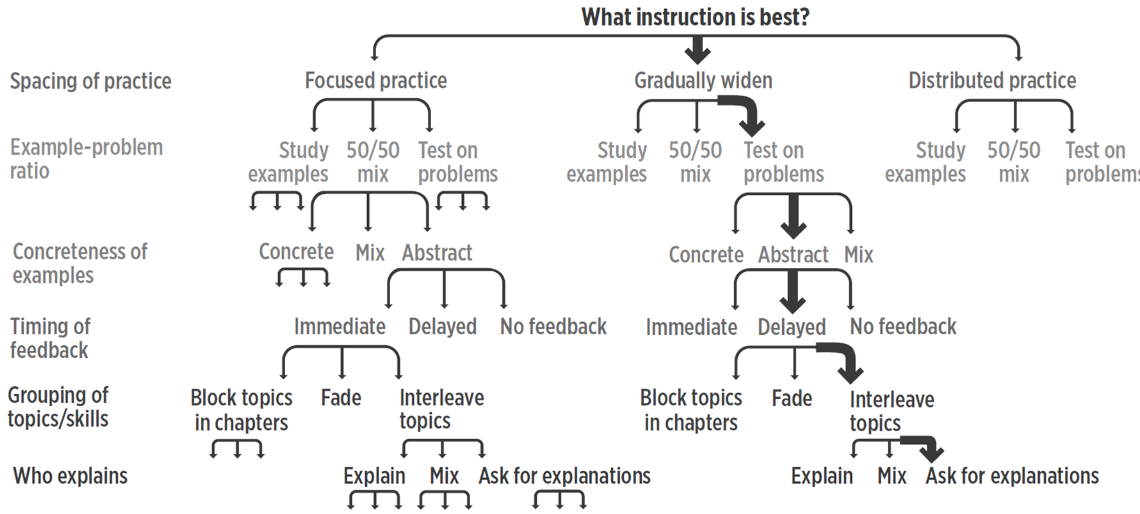

Figure 3. An array of different instructional options with one path selected (Cheung & Slavin, 2013).

students practice a topic and successfully complete the block of problems for that topic, ALEKS PPL considers this topic "learned." To "master" a topic, students must successfully answer a question from this problem type on a Knowledge Check assessment (ALEKS, 2018a). Knowledge Checks are formative assessments that interleave the problem types from previously learned topics. Interleaved practice is where problems are rearranged and presented in an intermixed order (Rohrer et al., 2015). Knowledge Checks are required after the student has spent a few hours in the program and have learned a certain number of topics (ALEKS, 2018a). Students can "master" a topic during a Knowledge Check but lose mastery of the topic if they unsuccessfully answer that type of problem on a later Knowledge Check. The student would need to relearn and practice those types of problems again. This combination of blocked and interleaved practice occurs throughout the use of the program. The key role of technology for practice is the capability "of describing hierarchies of mathematical skills in formal language that a computer can store, process and analyze" (Roschelle et al., 2017, p. 860). Students' detailed progress can be preserved and conceivably remediated by tracking mathematical skills in a database organized in terms of the relationships among mathematical skills (Roschelle et al., 2017). Intelligent tutoring systems, such as ALEKS PPL, have the capabilities to fulfill the role of technology for practicing skills.

How the ALEKS Program Promotes Individualized Practice

Programs like the ALEKS PPL have the potential to impact mathematics learning and placement in college mathematics courses because they provide opportunities for students to have individualized mathematics practice. Having students practice problems using ITS such as ALEKS PPL has the potential to expose students to the expected mathematics in the college curriculum and address the misalignment that is documented between high school and college mathematics (Barnett, Fay, Bork, & Weiss, 2013; Madison, et al., 2015; Venezia, et al., 2003). According to Strong American Schools (2008), some schools are missing high rigor in their high school mathematics courses; programs such as ALEKS PPL allows students to practice problems with high rigor. Because ALEKS PPL is an intelligent tutoring system, there is not a teacher bias that can affect students' grades. All students are graded equally and fairly with only correct answers achieving mastery of subjects and high scores on the placement exam. The ALEKS PPL exam is used by universities because students show that they can either solve the rigorous problems on the exam and are ready to take their college algebra course or they cannot, and therefore need remediation.

Several studies have been conducted on the effects of ITS and ALEKS with varying results. Steenbergen-Hu and Cooper (2013) conducted a meta-analysis on the effectiveness of ITS on K-12 students' mathematical learning. The results showed that the effects of ITS on learning were positive, yet small, where the average Hedge's *g* effect size ranged from 0.01 to 0.09. The effects were also not as good for low-achieving students and seemed to be more effective when the implementation period was less than a year and when the ITS was used as a supplemental tool rather being the main or only source of learning (Steenbergen-Hu & Cooper, 2013). Steenbergen-Hu and Cooper suggested that ITS' major strengths lie in supporting teaching and learning and not so much the replacement of teachers for the majority of content. These suggestions are in stark contrast to what Huang, Craig, Xie, Graesser, and Hu (2016) recommend. Huang et al. indicate the implementation of ITS, specifically ALEKS, as the only source of instruction was very effective in equally helping students with various individual differences such as gender, ethnicity, and SES, because teachers can treat students unfairly, even unintentionally. Although Karner (2017) found that ALEKS was effective at closing the gap by 30.4% between low-achieving students and those who are not. Fanusi (2015) found that implementing ALEKS did not have a significant effect on test scores for middle-grade students. The reasons for this discrepancy might be because of differences in research design. Karner studied whether students who took a supplemental course that uses ALEKS along with their regular Algebra 1 class would achieve more growth than students who were only enrolled in Algebra 1. In contrast, Fanusi compared the results of two remedial groups, one that implemented ALEKS and one that used a traditional teacher remedial setting, to see if the ALEKS group outperformed the traditional remedial group. ALEKS students performed statistically the same as the teacher group but did not perform better, and therefore, this was not considered effective. Fanusi did find that there was a correlation between the percentage of ALEKS concepts completed and the score on the Georgia Criterion Referenced Competency Test (CRCT) mathematics achievement end-of-year test. Bartelet et al. (2016) found that students are generally not self-motivated to use ITS if it is noncompulsory. Future research should look at the amount of time students need to spend using ITS to achieve the desired results and the effects that teachers have on the amount of time students spend using ITS.

One year after the publication of Steenbergen-Hu and Cooper's (2013) meta-analysis, the same authors published another meta-analysis that had very different findings. This meta-analysis differed from the previous one in that the focus was on college students' academic learning, whereas the previous one focused on K-12 mathematics learning. Not only did Steenbergen-Hu and Cooper find that the effects of ITS on college students' learning had a moderate positive effect that averaged from $g = .32$ unadjusted to $g = .37$ adjusted, but they also found that ITS outperformed all other methods of instruction and learning except human tutoring. The other methods of instruction included traditional classroom instruction, reading textbooks or computerized materials, computer-assisted instruction, laboratory or homework assignments, and a no-treatment control (Steenbergen-Hu & Cooper, 2014). Steenbergen-Hu and Cooper found no statistically significant difference between the effectiveness of different ITS programs or subjects. Two of the included studies used ALEKS with an average effect size of $g =$

.46 adjusted and g = .34 unadjusted. The study reported that the effect of ITS used for mathematics was g = .59 adjusted and g = .65 unadjusted. Another notable difference between the two meta-analyses researched by the authors is that the studies in the second analysis were generally using ITS for a short period of time and had small sample sizes.

The results of the two meta-analysis studies suggest that ITS may work better for older students than younger students. More research needs to be done in the area of ITS that can show more homogeneity in the results. This can be accomplished by providing a control group and using equivalent classes for comparison. Meta-analyses should compare studies that use ITS for equivalent amounts of time.

Summary

The reviewed literature showed that the mathematics taught in high schools is not aligned with the mathematics needed to register for and succeed in college-level mathematics, and students are graduating from high school underprepared for college-level mathematics. The consequences for students are to take remediation courses at college, which cost time and money and jeopardize their chances of graduation. The development of educational software, such as ALEKS PPL to supplement mathematics instruction and provide individualized learning, shows promise to address the mathematics misalignment. These programs allow students to see their mathematics deficiencies before they graduate from high school, allowing them to remediate before enrolling in college. Examining how the ALEKS PPL supports students' mathematics preparation contributes important insights to the current literature on ITS.

CHAPTER III

METHODS

Introduction

This dissertation used a data set collected by the researcher under approved IRB Protocol #9350 (see Appendix B). The researcher met with the members of the dissertation committee and received approval to use this existing data set on May 8, 2019. The collection of data required one full academic year to complete.

Purpose and Research Questions

The purpose of this study was to examine relationships between high school students' performance in ALEKS PPL Modules and performance on the ALEKS College Mathematics Placement Exam. Three main research questions guided this study.

1. How does assignment to the ALEKS PPL PreCalculus Learning Modules affect growth over time on the ALEKS PPL Mathematics Placement Exam?
2. What is the difference between the Non-ALEKS PPL Group and the ALEKS PPL Group in the percentage of students who score high enough to place into College Algebra according to the ALEKS PPL Mathematics Placement Exam?
3. What factors (module time, module mastery scores, teacher, exam time) influence student outcomes on the ALEKS PPL Mathematics Placement Exam for those who were assigned to work on the modules?

Research Design

This study used a quasi-experimental design to determine how the use of ALEKS PPL Modules by high school students was related to the students' performance on the

ALEKS PPL Mathematics Placement Exam. The design was quasi-experimental because students were not randomly assigned to high school classes to participate in this study. In the existing data set, there were students in high school mathematics classes using ALEKS PPL Modules and other students in Non-ALEKS PPL classes. Classes in the ALEKS PPL Group had their regular mathematics class sessions supplemented with ALEKS PPL Modules. Classes in the Non-ALEKS PPL Group participated in regular mathematics class sessions and did not use ALEKS PPL Modules. A quasi-experimental design was most appropriate for this study because it allowed the researcher to make causal inferences as long as data collected can make opposing explanations or threats to internal validity virtually implausible (Johnson & Christensen, 2008). Figure 4 illustrates the quasi-experimental nonequivalent research design used in the study.

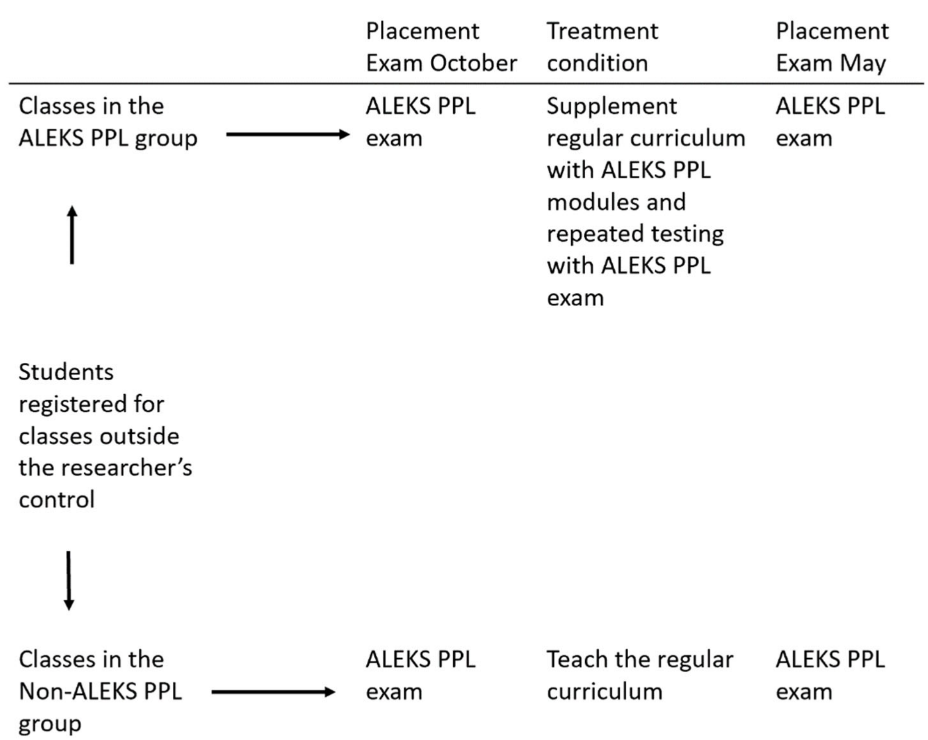

Figure 4. Quasi-experimental nonequivalent research design.

Participants and Setting

The participants in the existing data set were 100 high school students, ages 16-18. All of the students were enrolled in the same school district in a state in the Intermountain Western U.S. Approximately 78% of the participants self-reported as Caucasian and 54% of the population self-reported as female. The school district serves approximately 80,000 students in grades K-12 and has a minority enrollment that is 19% of the student body (majority Hispanic). Students in this school district have shown a mathematics proficiency rate of 53%, which is higher than the state's average of 46%. Furthermore, 27% of the students in this school district are eligible for free lunch or reduced lunch, which indicates that they are in homes designated as low socio-economic status, compared to the state's overall average of 35%. This district also has a student to teacher ratio of 25:1, which is the highest of any public school district in the state.

The students who participated in the data collection were chosen from a convenience sample and were enrolled in nine different class sections of College Prep Mathematics during their senior year of high school. The nine mathematics class sections were taught by six different teachers. The students in the participating classes had a variety of mathematical backgrounds. Some of the students could be missing some credits because they might have failed one of the terms of their previous mathematics courses and most likely had gaps in their mathematical knowledge. Other students could have had a good knowledge of high school mathematics, depending on the level of mastery they achieved during their previous mathematics classes. The ALEKS PPL modules are designed to support students' mathematical learning by identifying and filling in potential gaps in student learning. The College Prep Mathematics course in which students were enrolled accommodates students with a wide range of mathematical knowledge backgrounds.

The 100 students who participated in the data collection were in two subgroups. The first sub-group was called the ALEKS PPL Group (*n* = 73). The students in the ALEKS PPL Group used the ALEKS PPL program as a supplement throughout their mathematics classes during one full academic year. The students in this group came from three different high schools and six different class sections of College Prep Mathematics. The second sub-group was called the Non-ALEKS PPL Group (*n* = 27). The Non-ALEKS PPL Group did not use the ALEKS PPL program throughout the academic year. The students in this group came from two different high schools and three different class sections of College Prep Mathematics. Table 1 shows the number of participants with each teacher and participating school.

Table 1

Numbers of Schools, Classes, Teachers, and Participants in the Study

Location	Number of classes	Number of teachers	ALEKS PPL group	No. of participants in each class	Total no. of participants
High School A	3	2	Yes	4, 22, 8	34
High School B	1	1	Yes	10	10
High School C	1	1	No	7	7
High School D	2	1	Yes	21, 8	29
High School E	2	1	No	8, 12	20
TOTAL	9	6			100

Data Sources and Measures

The existing data set came from the ALEKS Corporation and includes three types of measures for the quantitative analysis: (1) ALEKS PPL Mathematics Placement Exam Scores from October and May, (2) ALEKS PPL PreCalculus Learning Module Mastery Scores for the ALEKS PPL Group, and (3) ALEKS PPL Time Data.

The fourth source of data, collected for informational use only, was provided by teachers at the end of the academic year in the form of a Teacher Implementation Report. All of the data to be used in this study, except for the Teacher Implementation Report, came from the ALEKS Corporation in the form of an Excel spreadsheet. These measures and sources of data are described in the sections that follow.

About the ALEKS PPL Program

ALEKS PPL is an artificially intelligent web-based learning and assessment system. Research performed by a team of software engineers, mathematicians, and cognitive scientists from New York University and the University of California, Irvine developed the educational technology (McGraw-Hill Education, 2020b). These researchers were pioneers in adaptive learning and studied how students learn mathematics and the interrelationship between mathematical topics which is the basis behind Knowledge Space Theory (McGraw-Hill Education, n.d.). The ALEKS Corporation acquired the software under a private, global, everlasting license, and ultimately, McGraw-Hill Education acquired ALEKS Corporation in 2013. The ALEKS PPL Mathematics Placement Exam was designed with the support of a large grant from the National Science Foundation at UC Irvine in 1994 (ALEKS, 2019).

ALEKS PPL Mathematics Placement Exam Scores

The first measure was students' scores on the ALEKS PPL Mathematics Placement Exam. The purpose of the ALEKS PPL Mathematics Placement Exam is to gather information about the current knowledge state of the student and create an instructional plan that can teach students topics that they are most ready to learn (McGraw-Hill Education, 2020a; Yilmaz, 2017). The exam covers 314 interrelated mathematics topics by asking 30 questions and takes about one hour for students to complete. Table 2 shows the number of topics that are examined in each of the 11 problem types on the placement exam.

All of the questions on the exam are open response, meaning that none of the questions are multiple-choice or true/false. The students who participated in the data

Table 2

Topics Covered by Problem Types in ALEKS Placement Exam

Placement assessment problem types	Number of topics
Whole numbers, fractions, and decimals	37
Percents, proportions, and geometry	32
Signed numbers, linear equations, and inequalities	53
Lines and systems of linear equations	27
Relations and functions	22
Integer exponents and factoring	30
Quadratic and polynomial functions	21
Rational expressions and functions	23
Radicals and rational exponents	20
Exponentials and logarithms	20
Trigonometry	29

collection for the existing data set had between two and five placement exam scores, depending on how many times they took the exam. For example, students in the Non-ALEKS PPL Group took the exam two times and have two Mathematics Placement Exam scores (October and May). Students in the ALEKS PPL Group took the exam between two and five times, and, therefore, they had a range of scores. Every student's exam was different because questions are based on answers to previous questions. The scores are reported by ALEKS Corporation in the form of a percent between 0 and 100. Each time a student gets a Mathematics Placement Exam score, the score represents the percentage of the 314 topics on which the student scored correctly.

The exam can identify placement in college courses from Basic Mathematics up to Calculus 1. Students receive a score accompanied by a table of cutoff scores that are aligned with corresponding mathematics courses at the local universities in their area. Table 3 shows the table of cutoff scores given to the students who were participants in the

Table 3

ALEKS PPL Cutoff Scores and Corresponding Mathematics Courses for Universities in this Study

ALEKS PPL score	Corresponding university course(s)
0-18	MAT 0950 (Beginning Algebra)
19+	MAT 1000, MAT 1035
30+	MAT 1010 (Intermediate Algebra)
32+	STAT 1045
38+	MATH 1055
46+	MAT 1030, STAT 1040, MATH 1050 (College Algebra), MATH 1090
61+	MATH 1060, MATH 1100, MGMT 2240, MATH 2010, STAT 2040
76+	MATH 1210 (Calculus)

existing data set. The scores students receive can be aligned with Table 3, allowing students to see which course they can enroll in at their local university.

ALEKS PPL PreCalculus Learning Module Mastery Scores

The second measure was the ALEKS PPL Mastery Scores. This data came from the ALEKS PPL PreCalculus Learning Modules. The PreCalculus learning modules have 246 topics divided among eight problem types. The problem types and number of associated topics are shown in Table 4. This data set was only available for the ALEKS PPL Group because the Non-ALEKS PPL Group did not work in the ALEKS PPL Learning Modules. There are two types of mastery scores: Initial Mastery Scores (which indicate initial mastery of module topics learned) and Final Mastery Scores (which indicate final mastery of module topics learned). Each student will have two items of log data: (1) the number of initial topics mastered, and (2) the final number of topics mastered. The mastery scores are given as a percent from 0 to 100. This percent

Table 4

Topics Covered by Problem Types in Prep for PreCalculus Learning Modules

Prep for precalculus learning modules problem types	Number of topics
Real numbers	30
Equations and inequalities	32
Exponents and polynomials	44
Lines and systems of linear equations	33
Functions and functions	29
Rational expressions	27
Radical expressions	26
Geometry	25

represents the number of topics mastered in the PreCalculus learning module out of the 246 topics total.

ALEKS PPL Time Data

The third measure was time data. There were two types of time measures. One measure of time, based on the ALEKS PLL Learning Modules, is the cumulative amount of time students spent logged in to the PreCalculus Learning Modules (called “module time”). The other measure of time was based on the ALEKS PPL Placement Exam. This was the amount of time students spent taking each exam (called “exam time”). The “module time” data was collected throughout the academic school year each time the student logged in, either at home or at school. This data set includes one data point for each student in the ALEKS PPL Group and is represented in hours and minutes. The “exam time” data was the amount of time students spent taking the exam. Students in the ALEKS PPL Group and the Non-ALEKS PPL Group will have one data point for each time they took the exam. This data set is represented in hours and minutes. Each student will have at least two data points for this data set but could have up to five if they took the exam all five times. The time data allows the researcher to examine if the amount of time the student spent in the modules or taking the exam is related to their exam scores.

Teacher Implementation Report

The fourth source of data was gathered for informational purposes only and came from a Teacher Implementation Report. Only teachers who worked with students in the ALEKS PPL Group completed the report. Teachers responded to a series of questions asked to gather information on their implementation of the ALEKS PPL Modules throughout the academic year. Teachers were asked to respond to twelve questions and their responses were recorded with a cell phone. The questions used to gather information for the report can be found in Appendix A. The purpose of this report will be to give the researcher insight into how each teacher implemented the ALEKS PPL modules into their class. This information will help to provide information on the priority that the ALEKS PPL modules were given by the teacher, the teacher's opinion of the program, the time that the teacher devoted to the program, and any technical or implementation issues that arose during the academic year.

How the Researcher Obtained the Data Set

There were three stages of data collection: permission to proceed, data collection, and data handling (Ajewole & Odaibo, 2009). Permission to perform this research was granted by the Institutional Review Board (IRB) of Utah State University (see Appendix B). The researcher obtained written permission to collect and analyze data from the school district through the director of research and evaluation of the school district. The data from this study was obtained from nine classes of College Prep Mathematics taught by six teachers. Because it is imperative to keep data organized and secure (Ajewole & Odaibo, 2009), the researcher set up a Box account to enable the transfer of all data securely between the teachers and researcher. One of the teachers accessed the data from ALEKS PPL and deidentified the data before uploading it to a secure Box account that only the researcher and teacher could access.

A senior manager from ALEKS Corporation came to one of the teacher's classrooms to train the researcher and three of the four teachers whose classes were participating in the ALEKS PPL Group. The training lasted for approximately 1.5 hours and covered student setup, content, and additional features. The teachers decided to have the students take the first placement exam before fall break in October. The teachers chose the PreCalculus module because it aligned most closely with the objective of the College Prep Mathematics course in which the students were enrolled. The fourth teacher who missed the meetings received training via WebEx from the senior manager before administering the first placement exam. The two teachers in the Non-ALEKS PPL Group received a short WebEx training before proctoring their first exam.

Students who returned a signed permission form approved by IRB were included in the study. All students in both the ALEKS PPL Group and the Non-ALEKS PPL Group created an account with ALEKS PPL and set up a username and password using laptops provided by the school. Students then logged into ALEKS PPL and completed a demographic questionnaire and began a tutorial on how to use the system. Students started the exam after they completed the tutorial. Teachers proctored the exam to ensure that students did not use calculators or outside sources. The exam was approximately 30 open response questions and covered material from 314 topics. Most students finished the exam in one class period. Those who did not finish completed the exam the next time they came to class. Students were able to see their scores upon completion of the exam. During the academic year, students in the ALEKS PPL Group took the exam up to five times. Teachers administered those exams in October, November, December, March, and

May. The Non-ALEKS PPL Group took the exam only twice—once in October and once in May.

The purpose of the ALEKS PPL modules was to provide an individualized instructional plan that provided some basic teaching and practice for students on topics that they are most ready to learn. ALEKS PPL provides students a learning page before starting to work on a new topic. The learning page provides an example of a problem and explains how to solve it. Students then continue to practice working on the topic by solving additional problems. Students worked on the PreCalculus modules throughout the academic school year during each class period for about 20 minutes, starting in early October and ending in late May. In May, the researcher received the deidentified ALEKS data and gathered information from the Teacher's Implementation Reports to complete data collection.

Data Analysis

This section details the data analysis process used with each measure to answer the three research questions. The measures used in this analysis were: (1) ALEKS PPL Mathematics Placement Exam Scores, (2) ALEKS PPL PreCalculus Learning Module Mastery Scores, and (3) ALEKS PPL Time Data (i.e., exam time and module time). According to Anastas (1999), it is imperative to organize and summarize the data to describe the data more efficiently. In this study, the quantitative data were exported from ALEKS PPL into an Excel spreadsheet. Table 5 aligns each research question with the data measurement source and analysis method.

Table 5

Description of Research Question, Measures, and Data Analyses Conducted in the Study

Research question	Measures	Data analyses
1. How does assignment to the ALEKS PPL PreCalculus Learning Modules affect growth over time on the ALEKS PPL Mathematics Placement Exam?	ALEKS Mathematics Placement Exam scores in October and May	2X2 Mixed ANOVA DV = exam scores (continuous, both October and May) IVbs = group (0 = control, 1 = treatment) IVws = date (1 = October, 2 = May)
2. What is the difference between the Non-ALEKS PPL Group and the ALEKS Group in the percentage of students who score high enough to place into College Algebra according to the ALEKS PPL Mathematics Placement Exam?	ALEKS Mathematics Placement Exam scores in October and May; Log data on May exam time	Logistic Regression DV = post exam score (in May only) higher than cut off score (binary, 0=no, 1=yes) IV = group (binary, 0 = control, 1 = treatment) CV1 = exam time taken (in May only, continuous minutes) CV2 = exam score (continuous, in October only)
3. What factors (module time, module mastery scores, teacher, exam time) influence student outcomes on the ALEKS PPL Mathematics Placement Exam, for those that were assigned to work on the modules?	ALEKS Mathematics Placement Exam scores in October and May; Log data on exam time and cumulative module time; Final module mastery scores	Multiple Linear Regression DV= exam growth over time (continuous exam score difference, May - Oct) IV1 = difference in exam time taken (May-Oct, continuous minutes) IV2 = difference in module mastery scores (continuous, percentage) IV3 = cumulative module time (continuous, minutes) IV4 = teacher (4 different teachers, ID = 1, 2, 3, 4)

ALEKS PPL Mathematics Placement Exam Growth Analysis

The first research question examined how students' assignment to the ALEKS PPL PreCalculus Learning Modules (group) affected growth over time (October vs. May) on the ALEKS PPL Mathematics Placement Exam. This question allowed the researcher to investigate the effectiveness of assigning ITS in high school settings. The researcher used side-by-side boxplots of the exam scores between October and May for the two groups to show the between and within-group variation (Moore & McCabe, 2002). The researcher will use a side-by-side graph of means to display differences in scores between groups. Summary statistics for the October exam, May exam, and exam growth over time gains were calculated, including mean, median, standard deviation, and range of scores.

The 2x2 mixed analysis of variance (ANOVA) was used to assess differences in ALEKS PPL Mathematics Placement Exam scores (dependent variable) by treatment group (independent variable – between-subject) at the two times (independent variable – within-subjects) to reveal any differences between the mean growth by assignment of ALEKS PPL (Moore & McCabe, 2002). The full sample of participants (N = 100) was utilized for this analysis to answer the first research question. The dependent variable was the ALEKS PPL Mathematics Placement Exam scores from October and May only. The independent variables were (1) the independent group (group), either the ALEKS PPL Group or the Non-ALEKS PPL Group, which is the between-subject variable; and (2) assessment date (date), taken in October or May, which is the within-subject or repeated-measures variable. Prior to the mixed ANOVA, the researcher examined the underlying assumptions. This included generating normal quantile plots for October and May exam scores and examining assumptions of normality. Homogeneity of variance was assessed via Leven's Test (Moore & McCabe, 2002). The test showed that the standard deviations were equal, and assumptions of normality were met. The omnibus F-test of the mixed

ANOVA revealed that treatment assignment effected change in ALEKS PPL Mathematics Placement Exam scores over time (group x date interaction), so a post hoc Cohen's d effect size was computed on the May exam scores.

College Algebra Placement Analysis

Logistic regression was used in the analysis for the second research question to assess the difference between the Non-ALEKS PPL Group and the ALEKS Group in the probability that a student will score high enough to place into College Algebra (Score ≥ 46%). Prior to the analysis, the researcher created visual analyses of bar graphs to show the percentage qualifying in the two groups, as well as stratified by class. This allowed the researcher to see class differences which could be due to students being nested within classes. If this happens, it could influence the interpretation of the results. Within the full sample of participants ($N = 100$), the dependent variable was the ALEKS PPL Mathematics Placement Exam score from May dichotomized above or below the cut-off score to place into college algebra (0 = no, 1 = yes). The independent variable was the student group (ALEKS PPL or Non-ALEKS PPL). Covariates included how much time students spent taking the May exam (minutes), as well as their initial placement exam score (from October). The metric that was used for exam scores was percent. This allowed for a good interpretation of the logistic regression odds ratio. This is because the interpretation of the odds ratio works by increasing the independent variable one unit, in this case, 1%, and then interpreting the odds ratio to describe the odds of the dependent variable occurring.

Factors that Influence Student Outcomes Analysis

Multiple linear regression was used to addresses the third research question that focuses on potential factors that influenced students' growth on the ALEKS PPL Mathematics Placement Exam. This analysis included the students assigned to use the PreCalculus Learning Modules only (ALEKS PPL Group, *n* = 73). The dependent variable was defined as the difference in ALEKS PPL Mathematics Placement Exam scores in October and May. The independent variables were the difference in the amount of time spent working on the ALEKS PPL Mathematics Placement Exam (May exam time - October exam time spent in minutes), the difference in the percentage of topics mastered in the ALEKS PPL PreCalculus Learning Modules (final module mastery scores – initial module mastery scores), the amount of time logged into the ALEKS PPL PreCalculus Learning Modules (cumulative module time in minutes), and the teacher assigned to each student group (ID = 1, 2, 3, 4). Initially, the researcher conducted exploratory data analysis which included computing summary statistics, such as the mean, median, standard deviation, and range of scores, and visualizations of bivariate relationships with scatterplots and the correlation coefficients. A Wald test was used to assess the statistical significance of independent variables and follow-up variable inflation factors (VIF) will address potential issues with multicollinearity due to correlation between the supposed independent variables.

Limitations

The data analysis had some limitations that need to be considered. First, students were not randomly placed into groups or classes. The researcher did not have control over students' placement into classes or schools. Because of this, the generalization of the results of the mixed ANOVA may not be justified. The researcher also had no control over which classes chose to use the ALEKS PPL Modules and would receive the assigned treatment. Non-randomized studies are more prone to systematic and confounding biases (Moore & McCabe, 2002). For instance, it may be that the control group teachers are less engaged in the process and their students will have lower motivation to do well on the exams.

Another limitation of this study was the imbalance in groups. The researcher was able to find several schools that were willing to implement ITS into their classes. However, it was difficult for the researcher to find many classes that were willing to spend the time taking the exams without having the assigned treatment of working with the ALEKS PPL Modules. Imbalances can bias estimates of treatment effects and can increase their uncertainty. Furthermore, the small sample size and maturation were limiting factors of this study. Small sample size is associated with low statistical power, inflated effect size estimation, and low reproducibility (Button et al., 2013). Several students during the study withdrew from the course and therefore did not take the final ALEKS PPL Placement Exam.

Another limitation was the testing effect. Many students in the ALEKS Group took the ALEKS PPL Mathematics Placement Exam several times during the study. Students in the Non-ALEKS Group only took the exam twice. This could have a positive or negative effect on exam scores (Christ, 2007). Finally, unequal teacher engagement can affect student outcomes. More engaged teachers can find ways to dedicate more time for students to work with the program in class and can provide incentives for students to try their best on the exams. Teachers disengaged with the ALEKS PPL program can choose to not have students work on it in class and not encourage the use of the program. This can affect exam scores if students feel rushed and not given the proper amount of time to take the exam. The teacher implementation report will be used to help with the interpretation of the data and the fidelity of the teacher implementation. The results are presented and take into consideration these limitations.

CHAPTER IV

RESULTS

The purpose of this study was to examine relationships between high school students' performance in Assessment and LEarning in Knowledge Spaces (ALEKS) Placement, Preparation, and Learning (PPL) Modules and performance on the ALEKS College Mathematics Placement Exam. A quantitative, quasi-experimental research design was chosen to examine this relationship. The research questions guiding this study were: (1) How does assignment to the ALEKS PPL PreCalculus Learning Modules affect growth over time on the ALEKS Mathematics Placement Exam? (2) What is the difference between the Non-ALEKS PPL Group and the ALEKS PPL Group in the percentage of students who score high enough to place into College Algebra according to the ALEKS PPL Mathematics Placement Exam? (3) What factors (module time, module mastery scores, teacher, exam time) influence student outcomes on the ALEKS PPL Mathematics Placement Exam for those who were assigned to work on the modules? This chapter is organized by the three research questions.

ALEKS Learning Modules Effect on the ALEKS Placement Exam

The first research question examined whether assignment to the ALEKS PPL PreCalculus Learning Modules effected growth over time on the ALEKS Mathematics Placement Exam. The first part of the analysis to answer this research question included summary methods (e.g., box plots and descriptive statistics). In the second part of the analysis, the researcher used a 2 x 2 mixed ANOVA. The figures and tables below show comparisons between the students who completed both the October exam and the May exam in the ALEKS Group (n = 73) and the Non-ALEKS Group (n = 27). Figure 5 shows side-by-side boxplots comparing the exam scores of the ALEKS Group with the Non-ALEKS Group. The median is shown by the horizontal line in the boxplot and the mean is shown by the x.

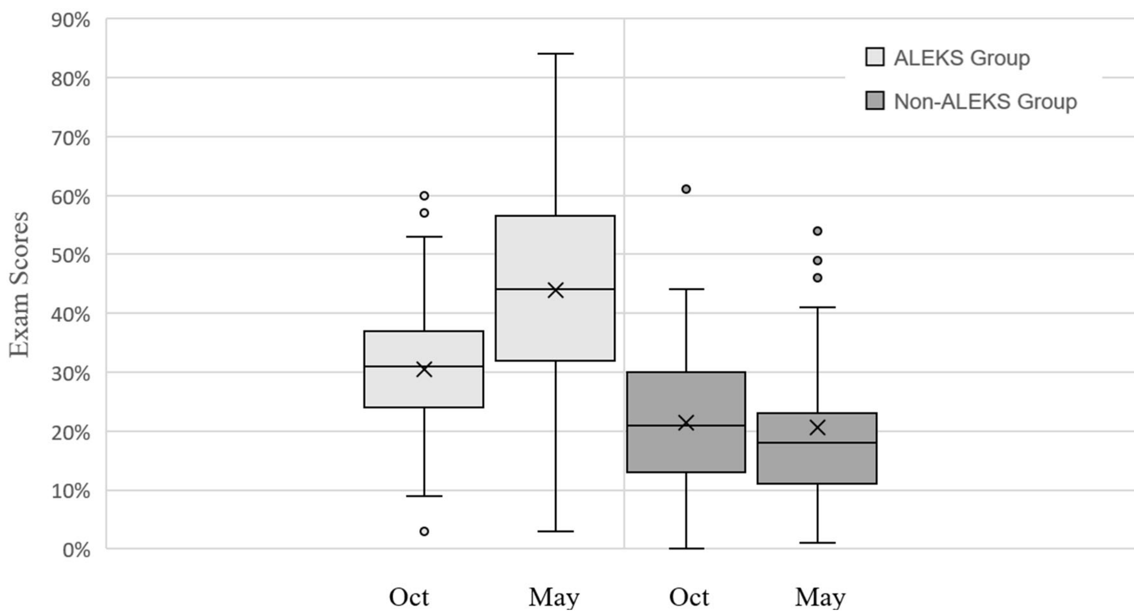

Figure 5. Boxplots of ALEKS Group vs Non-ALEKS Group for comparison of exam scores across time.

As Figure 5 shows, the ALEKS Group had a higher mean average on the October Exam compared to the Non-ALEKS Group. This shows that the student exam scores were not equal between the groups at the beginning of the school year. The figure also shows that the ALEKS Group achieved greater gains in their exam scores from October to May compared to the Non-ALEKS Group. This suggests that working with the PreCalculus Learning Modules may have been effective in improving performance on the exam for the students who participated in this study.

Table 6 shows descriptive statistics of the exam scores for the ALEKS Group and the Non-ALEKS Group.

Table 6

Descriptive Statistics of ALEKS Group and Non-ALEKS Group Exam Scores

Group	*n*	Min	Max	Mean	*SD*
ALEKS Group Oct Score	73	3	60	30.425	11.502
ALEKS Group May Score	73	3	84	43.973	17.007
Non ALEKS Group Oct Score	27	0	61	21.482	13.051
Non ALEKS Group May Score	27	1	54	20.556	14.001

As Table 6 shows, both groups had very similar minimum scores on the October and May exams and both groups had the same maximum score on the October exam. Additionally, there was a significant difference in the maximum score for May with the ALEKS Group having a high student score at 84% and the Non-ALEKS Group having a high student score at 54%. Most importantly, the mean scores for the ALEKS Group increased from 30.4% in October to 43.9% in May, while the mean score for the Non-ALEKS Group decreased from 21.5% in October to 20.6% in May. This shows that the ALEKS Group experienced greater overall gains in exam scores from October to May.

Figure 6 breaks down each group by teacher and uses boxplots to compare each group's exam scores from October and May. Figure 6 shows that every teacher in the ALEKS Group had students in their classes that averaged overall class gains on the exam from October to May. Conversely, the Non-ALEKS Group shows that one teacher

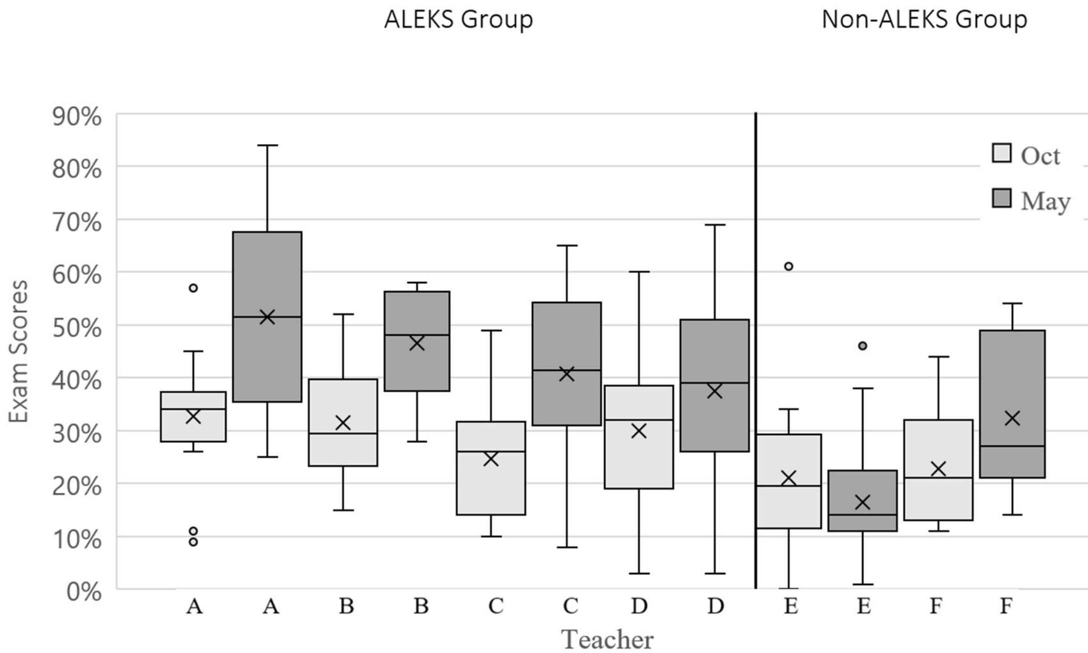

Figure 6. Boxplot of ALEKS and Non-ALEKS Group exam scores separated by group.

(Teacher E) had students in their class that averaged overall class losses on the exam, and one teacher (Teacher F) had students in their class that averaged overall class gains on the exam.

Table 7 shows descriptive statistics for the October and May exam scores separated by the teacher for each group. Table 7 shows that the October exam scores ranged from 3-61% and the May exam scores ranged from 3-84%. The overall mean exam scores for students taught by teachers in the ALEKS Group increased from October to May. This increase ranged from 7.6-18.7%. In contrast, the Non-ALEKS Group had October exam scores that ranged from 0-61% and May exam scores that ranged from 1-54%. The Non-ALEKS Group taught by Teacher E showed a decrease of 5% in mean exam scores from October to May, while the Non-ALEKS Group taught by Teacher F saw a 10% increase during that time frame. This shows that every individual class had

Table 7

Descriptive Statistics of ALEKS Group and Non-ALEKS Group Exam Scores Separated by Teacher

Group	*n*	Min	Max	Mean	*SD*
ALEKS					
Teacher A Oct. Score	26	9	57	32.769	9.572
Teacher A May Score	26	25	84	51.539	17.326
Teacher B Oct. Score	8	15	52	31.500	11.551
Teacher B May Score	8	28	58	46.625	10.555
Teacher C Oct. Score	10	10	49	24.600	12.048
Teacher C May Score	10	8	65	40.800	16.645
Teacher D Oct. Score	29	3	60	30.035	12.676
Teacher D May Score	29	3	69	37.552	16.041
Non-ALEKS					
Teacher E Oct Score	20	0	61	21.000	13.681
Teacher E May Score	20	1	46	16.400	11.052
Teacher F Oct Score	7	11	44	22.857	11.936
Teacher F May Score	7	14	54	32.429	15.512

overall mean score gains from October to May, except for the Non-ALEKS Group taught by Teacher E.

In order to test the null hypothesis, that assignment to the ALEKS PPL PreCalculus Learning Modules does not affect student's performance on the ALEKS Mathematics Placement Exam, the researcher assessed assumptions before performing a 2x2 mixed ANOVA. Because the two groups' distributions had skewness and kurtosis less than |2| for both the October exam and May exam (Lomax, 2001), assumptions of normality were satisfied (Schmider, Ziegler, Danay, Beyer, & Bühner, 2010). Furthermore, Levene's *F* test of equality variances showed that both the October, $F(1, 98) = .46$, $p = .499$, and May, $F(1, 98) = 2.27$, $p = .135$, exam scores met the homogeneity of variance at the .05 significance level. Box's test of equality of covariance $M = 4.15$, $F(3, 42071.9) = 1.34$, $p = .259$, failed to find evidence of violation of this assumption.

The 2x2 mixed ANOVA showed a significant interaction between group and date, $F(1, 98) = 19.16$, $\eta_p^2 = .16$, $p < .001$. This means that there was sufficient evidence to reject the null hypotheses. Assignment to the PreCalculus Learning Modules did affect students' performance on the ALEKS Mathematics Placement Exam for the participants in this study, such that those students in the ALEKS group increased their exam scores between October and May, $M_{diff} = 13.55$, $SE = 1.72$, $p < .001$, d = 0.87, 95% *CI* [10.14, 16.96], whereas their peers who were not assigned to use ALEKS exhibited no statistically significant change in mean performance, $M_{diff} = -0.93$, $SE = 2.83$, $p =.744$. Estimated marginal mean ALEKS PPL Mathematics Placement Exam are displayed in Figure 7 including 95% confidence intervals for all means.

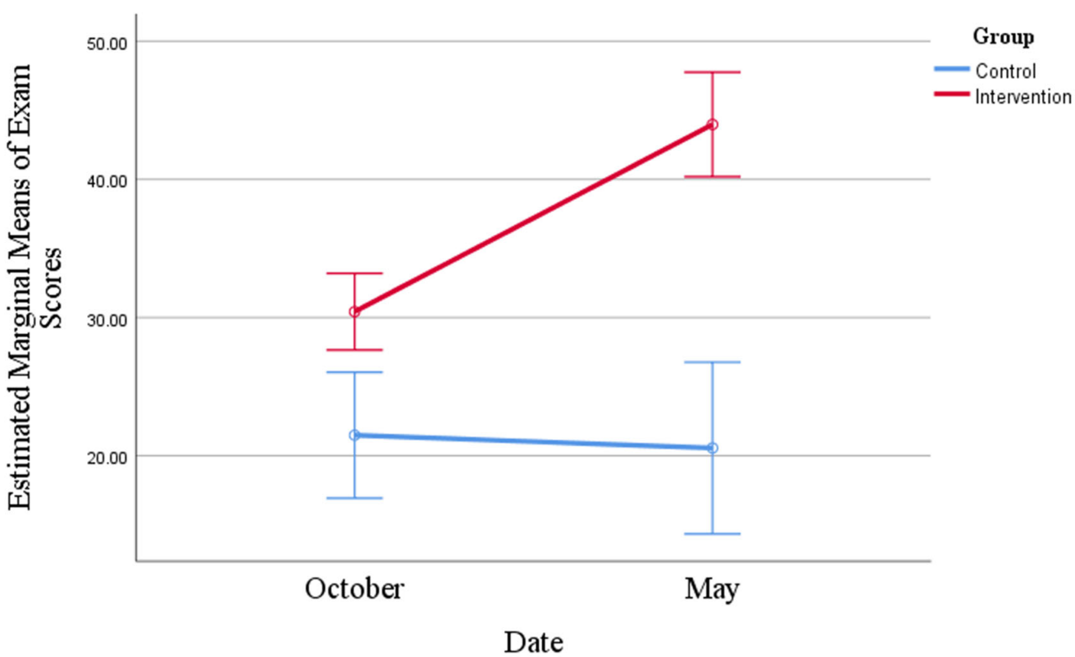

Figure 7. Estimated marginal mean from the 2x2 mixed ANOVA comparing the ALEKS PPL Mathematics Placement Exam given in October and May in both groups (Error bars: 95% CI).

Difference Between Groups in Percentage of Students Who Placed into College Algebra

The second research question examined the difference between the Non-ALEKS Group and the ALEKS Group in the percentage of students who scored high enough to place into College Algebra (according to the ALEKS PPL Mathematics Placement Exam). The analyses to answer this research question included summary methods and the use of logistic regression.

The first analysis examined the results for the Non-ALEKS Group taught by Teacher E. Because of the decrease in mean scores experienced by the students in this group, further inspection was needed to look at exam time separated by teacher. Figure 8 shows side-by-side boxplots comparing the ALEKS Group and the Non-ALEKS Group to examine the amount of time students spent taking the Mathematics Placement Exam.

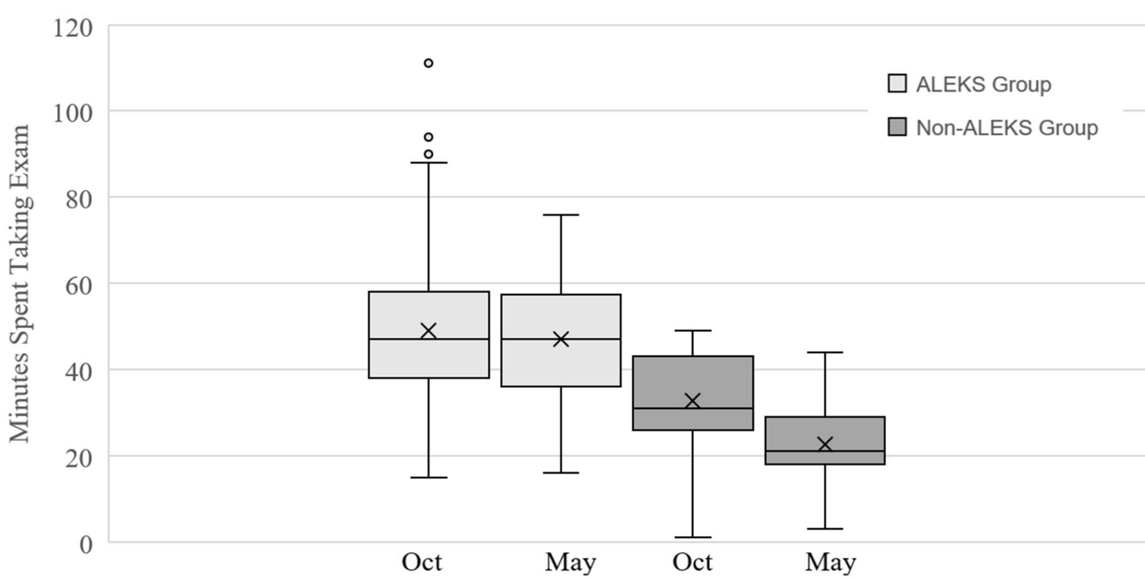

Figure 8. Boxplot of ALEKS Group vs Non-ALEKS Group comparison of exam time.

As Figure 8 shows, the mean and median time amount that students spent taking the Mathematics Placement Exam for the ALEKS Group was similar for the October exam and the May exam, with the spread being larger for the ALEKS Group during the October exam. In contrast, the mean and median time amount that students spent taking the exam for the Non-ALEKS Group showed a large decrease from October to May. This seems to imply that students in the Non-ALEKS Group did not spend as much time on the exam as students in the ALEKS Group, which could have impacted their exam scores.

Figure 9 shows a boxplot of the time spent taking the October and May exams for the ALEKS Group and the Non-ALEKS Group separated by group and teacher.

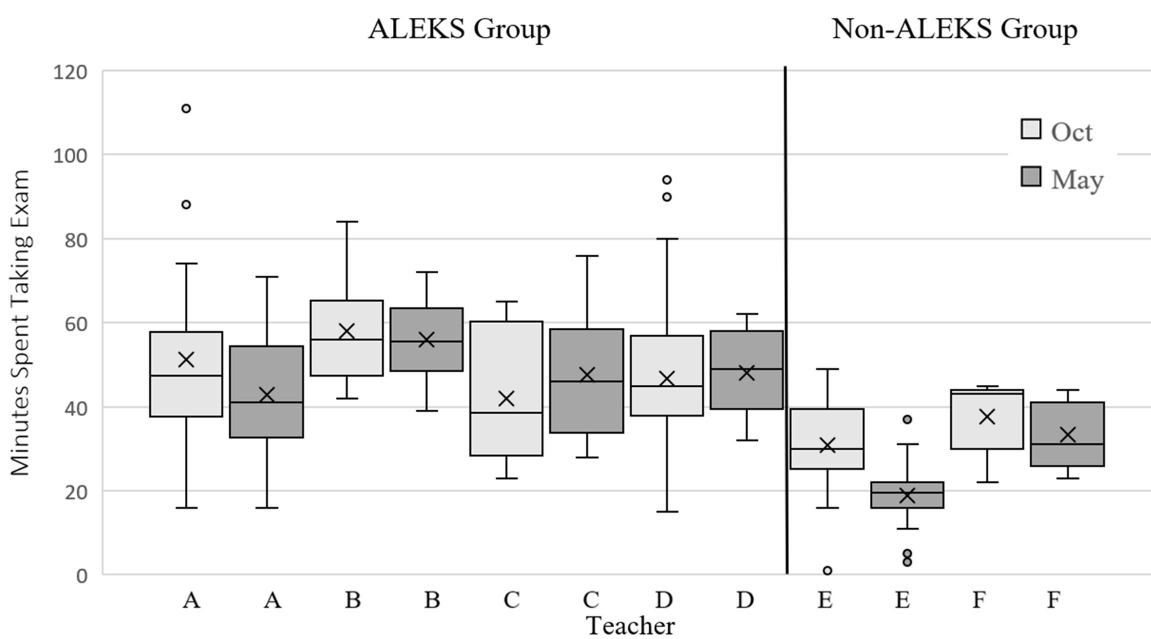

Figure 9. Boxplot of ALEKS Group and Non-ALEKS Group exam time separated by group and teacher.

As Figure 9 shows, all classes in the ALEKS Group are relatively similar in the amount of time students spent taking the exam in October and May. All of the students taught by teachers in the ALEKS Group had similar averages and spread between the October and May exams. The students in the Non-ALEKS Group had much lower median times on the May exam than the October exam. Additionally, the amount of time spent by the students in the class taught by Teacher E shows a significant drop-in exam time for the May exam compared to the October exam for that class, and in comparison with all of the other classes in the study. This shows that the students in Teacher E's class spent much less time taking the May Exam when compared with all of the other classes.

Table 8 shows side-by-side comparisons of the time spent taking each exam and descriptive statistics for the time spent on each exam for the ALEKS Group and the Non-ALEKS Group separated by teacher.

Table 8

Descriptive Statistics of the ALEKS Group and the Non-ALEKS Group Exam Times Separated by Teacher

Group	*n*	Min	Max	Mean	*SD*
ALEKS					
Teacher A Oct Time	26	16	111	51.346	19.401
Teacher A May Time	26	16	71	42.923	14.781
Teacher B Oct Time	8	42	84	58.125	13.109
Teacher B May Time	8	39	72	56.000	10.254
Teacher C Oct Time	10	23	65	41.900	16.086
Teacher C May Time	10	28	76	47.700	15.093
Teacher D Oct Time	29	15	94	46.724	19.153
Teacher D May Time	29	32	62	48.103	9.861
Non-ALKES					
Teacher E Oct Time	20	1	49	30.950	11.344
Teacher E May Time	20	3	37	18.950	8.660
Teacher F Oct Time	7	22	45	37.571	8.734
Teacher F May Time	7	23	44	33.429	8.182

As Table 8 shows, the mean time spent taking the exam was at least 41.9 minutes for the ALEKS Group. The greatest difference in mean time spent on the May exam compared to the October exam was less than 8.5 minutes for students in the ALEKS Group. This shows that the largest change in time from the October exam to the May exam was 8.4 minutes for the ALEKS Group. Furthermore, the students in the class taught by Teacher E had minimum exam times between 1-3 minutes and maximum exam times between 37-49 minutes. The maximum amount of time spent taking the May exam for the Non-ALEKS Group was 37 minutes for students in Teacher E's class and 44 minutes for the students taught by Teacher F. The mean time spent on the May exam was less than 19 minutes for the students in the class taught by Teacher E compared to over 33 minutes for the students in the class taught by Teacher F. This shows a large difference in the amount of time students spent taking the exam, with students in Teacher E's class (Non-ALEKS Group) spending considerably less time on taking the exam than students in Teacher F's class (Non-ALEKS Group), and also for every class in the ALEKS Group. It is important to note that Teacher E was the only one who reported having students take the exam on the last day of school.

The preceding tables and figures show that there was considerable variation in the amount of time students spent on the exam by class. There was also a decrease in exam scores from the October exam to the May exam for the students in the class taught by Teacher E. The low amount of time students spent taking the May exam likely impacted student scores. If students did not spend adequate time on the exam, it is likely that they did not perform to their true ability. Because 74% of the students in the Non-ALEKS

Group were in the class taught by Teacher E, the analysis of the Non-ALEKS Group is likely to be heavily swayed by this one teacher.

Figure 10 displays a bar graph to show the percentage of students who qualified to register for College Algebra based on their exam scores in October and in May for the two participating groups.

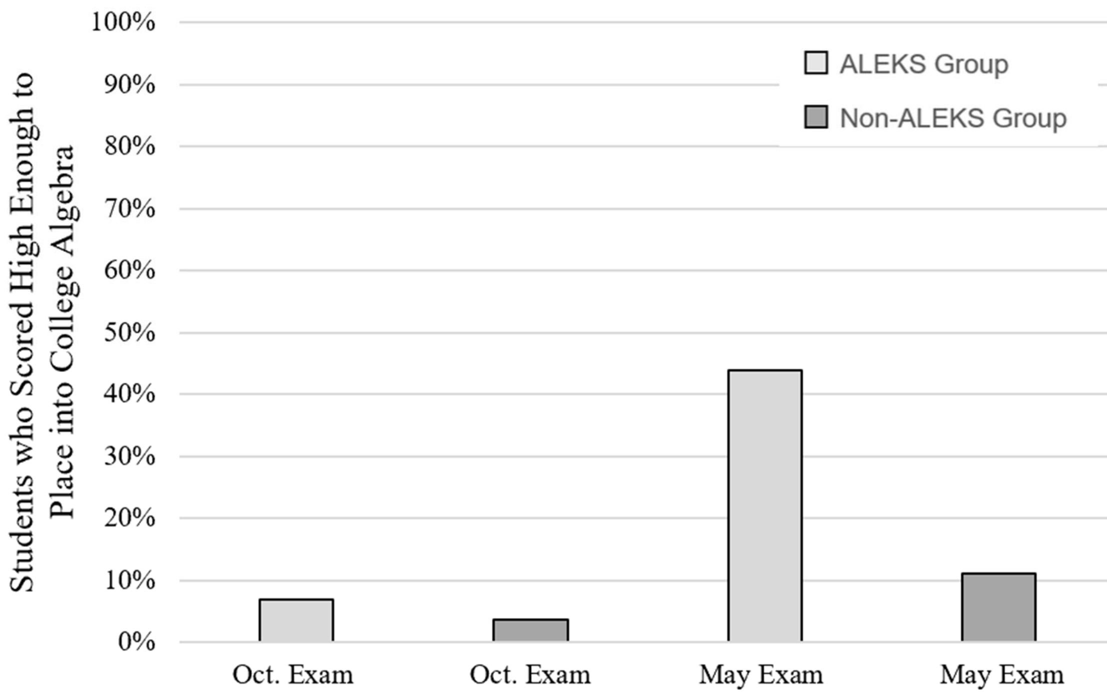

Figure 10. Percentage of students who qualified to register for College Algebra by group.

As Figure 10 shows, the two groups had similar percentages of students who qualified to take College Algebra according to their October exam scores (both less than 10%). In contrast, the ALEKS Group had a much larger percentage of students who qualified to register for College Algebra after taking the exam in May (44%) compared with the Non-ALEKS Group (11%). To get more insight about group differences, the researcher looked at the percentage of students who qualified for College Algebra by teacher. Figure 11 shows a bar graph with the percentage of students who qualified to register for College Algebra by teacher based on the May exam score.

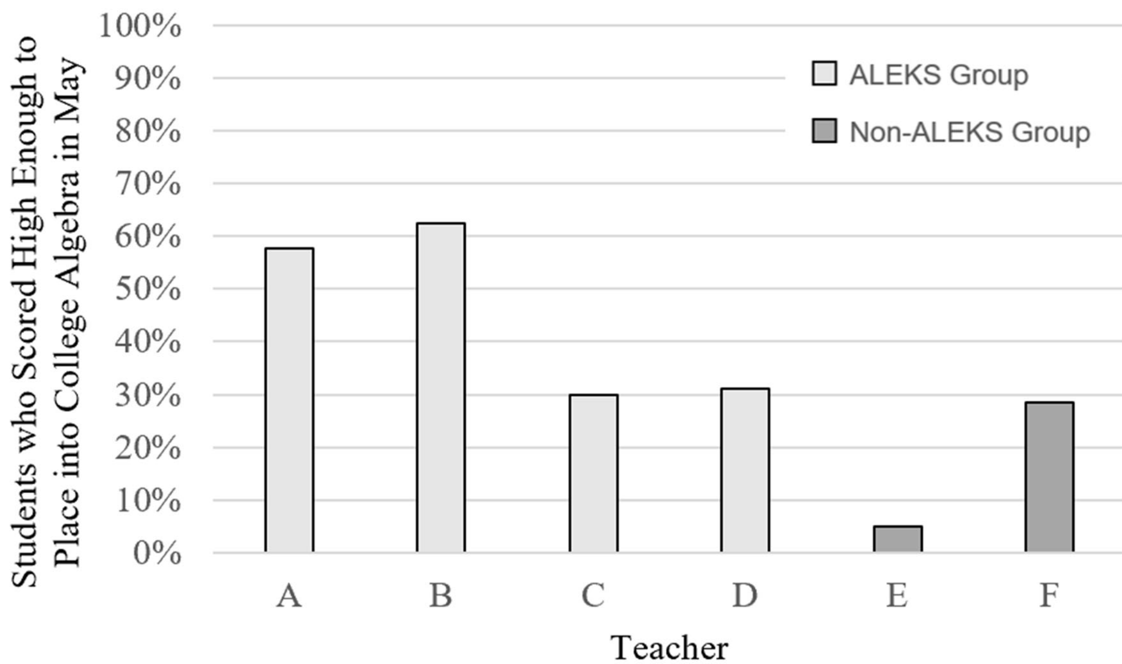

Figure 11. Percentage of students who qualified to register for College Algebra by teacher based on their May exam score.

As shown in Figure 11, two teachers in the ALEKS Group (Teacher A and Teacher B) had significantly higher percentages of students who qualified to register for College Algebra in May compared to all other teachers. Teacher F (in the Non-ALEKS Group) had a similar percentage of students who qualified for College Algebra as Teacher C and Teacher D (in the ALEKS Group). Only the students in the class taught by Teacher E performed significantly different than all other classes. The ALEKS Group had a range of percentages from 30-63% who qualified for College Algebra, while the

Non-ALEKS Group had a range of percentages from 5-29% who qualified for College Algebra, which is much lower than the ALEKS Group.

To examine this phenomenon, the researcher conducted a logistic regression analysis to investigate the difference between the Non-ALEKS Group and the ALEKS Group in the percentage of students who scored high enough to place into College Algebra (Score ≥ 46%) according to the ALEKS PPL Mathematics Placement Exam. The continuous predictor variables, including time students spent taking the May exam (minutes) and initial placement exam score (from October), were tested to verify that there was no violation of the assumptions of linearity of the logit. Because the interaction terms were not significant, the main effect did not violate the assumptions of linearity of the logit (Field, 2013). Additionally, collinearity statistics showed a tolerance greater than .1 and VIF less than 10, which does not indicate a problem for collinearity for all predictor variables (Field, 2013). Table 9 shows the collinearity diagnostics, which provide eigenvalues and variance proportions to investigate the possibility of multicollinearity.

Table 9

Collinearity Diagnostics with the Dependent Variable Cut-Score and the Three Predictor Variables: Group, May Exam Time, and October Score

				Variance proportions			
Model	Dimension	Eigenvalue	Condition index	(Constant)	Group	May exam time	Oct Score
1	1	3.686	1.000	0.010	0.010	0.010	0.010
	2	0.173	4.621	0.100	0.510	0.010	0.190
	3	0.089	6.432	0.500	0.050	0.050	0.800
	4	0.052	8.419	0.390	0.440	0.940	0.000

As shown in Table 9, the Eigenvalues are relatively close which does not indicate a problem with collinearity (Field, 2013). On the other hand, if the variance proportions have any predictors that contain large proportions on the same small eigenvalue then this would indicate that the variance of their regression coefficients are dependent (Field, 2013). Table 9 shows, for the predictor variable Group, that 44% of the variance of the regression coefficient is associated with eigenvalue number 4. Additionally, for the predictor variable May exam time, 94% of the variance of the regression coefficient is associated with this same eigenvalue. This shows that there may be collinearity among the variables Group and May exam time.

The outcome of interest for Research Question 2 was if students' scores were at least 46%. The possible predictor variables were Group (ALEKS or Non-ALEKS), May exam time, and October exam score. Additionally, the Hosmer-Lemeshow goodness-of-fit test was not significant ($p > .05$) indicating that the model was correctly specified (Field, 2013). These variables together accounted for about 39% of the variance (Nagelkerke R square = .391). The model resulted in the independent variables, Group ($p = .326$) and May exam time ($p = .178$) not being significant. However, the independent variable, October exam score, was found to be significant. Controlling for Group and May exam score, the predictor variable, October exam score, in the logistic regression analysis was found to contribute to the model. The parameter estimate unstandardized b = 0.095, SE = 0.026, $t(1) = 12.99$, $p < .001$. The estimated odds ratio favored a positive relationship, OR = 1.100, 95% CI [1.04, 1.16]. This shows a relationship between October exam scores and scoring at least 46% on the exam in May. This means that if a student's October exam score increases by 1%, then they are 10% more likely to score at least a 46% on the May exam. A logistic regression for group alone and group with May exam time was analyzed next, because diagnostics showed the possibility of multicollinearity.

The analysis for the logistic regression with Group as the only predictor variable had a significant Hosmer-Lemeshow goodness-of-fit test ($p < .001$), therefore this model was a poor fit. The independent variable, Group, was found to be significant and would have contributed to the model if the model had been a good fit. The parameter estimate unstandardized $b = -1.83$, $SE = .66$, $t(1) = 7.79$, $p = .005$. The estimated odds ratio shows that students in the ALEKS Group were 6.25 more likely to score at least 46% on the ALEKS Mathematics Placement Exam compared to the Non-ALEKS Group, $OR = 0.16$, 95% CI (0.04, 0.58).

Next, the researcher analyzed the logistic regression with the predictor variables Group and May exam time. The Hosmer-Lemeshow goodness-of-fit test was not significant ($p > .05$) indicating that the model was correctly specified (Field, 2013). These variables together accounted for about 21.1% of the variance (Nagelkerke *R* square = .201). The predictor variable Group was not significant ($p = .265$). However, the independent variable, May exam time, was found to be significant. Controlling for Group, the predictor variable, May exam time, in the logistic regression analysis was found to contribute to the model. The parameter estimate unstandardized $b = 0.04$, $SE = 0.02$, $t(1) = 4.83$, $p = .028$. The estimated odds ratio favored a positive relationship, $OR = 1.04$, 95% CI [1.01, 1.08], such that the odds for students' scores to be equal to at least

46% increases by 4% for every 1-minute increase of May exam time.

These results indicated that the October exam score was a predictor of students' May exam score being high enough to place into College Algebra. The results also showed that May exam time was a predictor of students' scores to be at least 46%. However, there was no evidence that group assignment (ALEKS or Non-ALEKS) was a predictor of placing into College Algebra.

Factors that Influence Student Outcomes on the Placement Exam

The third research question examined the factors (module time, module mastery scores, teacher, exam time) that may have influenced student outcomes on the Mathematics Placement Exam between October and May for the ALEKS Group only. The analyses to answer this research question included summary methods and a multiple linear regression. For example, Figure 12 shows a boxplot of the dependent variable, with the difference in exam scores from October to May, for teachers in the ALEKS Group. This was found by subtracting each student's October exam score from their May exam score. Most students show a gain, but some experienced a loss, indicated by a negative percentage.

The mean and median scores for the students taught by Teachers A, B, and C are all very similar across classes, as shown in Figure 12. Scores for students taught by Teacher D have a mean and median lower than the other teachers in the group. Only one teacher, Teacher B, showed gains for every student. Table 10 shows the descriptive statistics for all students in the ALEKS Group for the difference in exam scores.

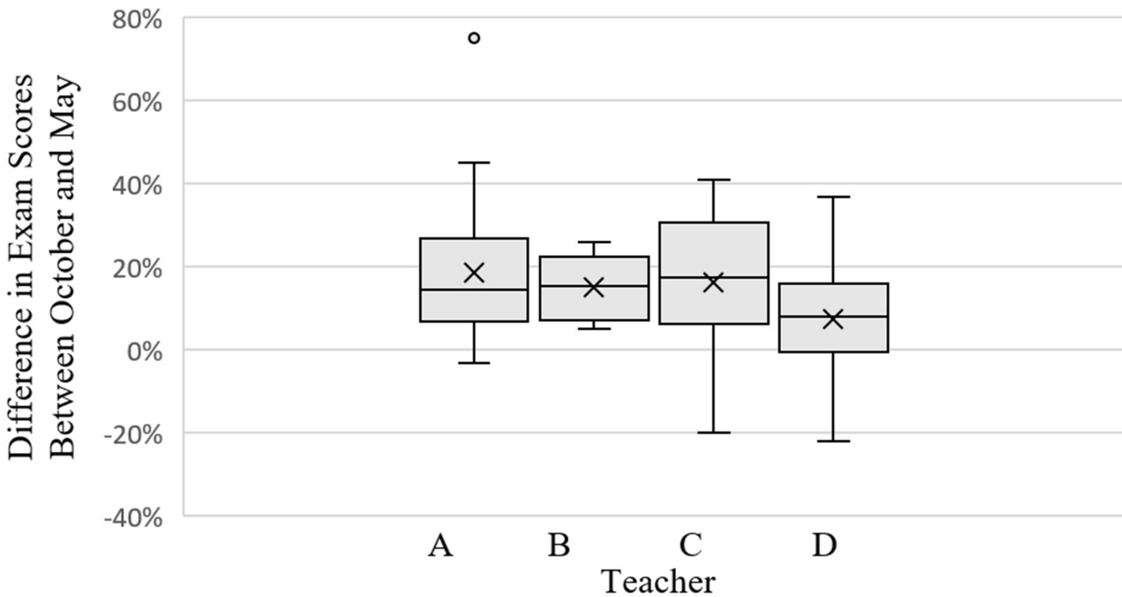

Figure 12. Difference of exam scores for the ALEKS Group by the teacher.

Table 10

Descriptive Statistics of Difference in Exam Scores Separated by Teacher

Teacher	*n*	Min	Max	Mean	*SD*
A	26	-3.000	75.000	18.769	16.929
B	8	5.000	26.000	15.125	7.990
C	10	-20.000	41.000	16.200	17.825
D	29	-22.000	37.000	7.517	13.574

As Table 10 shows, all of the students taught by Teacher B experienced gains on their May exam. The lowest student taught by Teacher A had a loss of 3%, while those taught by Teachers C and D had up to a 22% loss. Students taught by Teacher A had the highest overall mean gain of 19%, which was similar to the other teachers except for students taught by Teacher D, who had a mean gain of 8%.

Figure 13 shows a boxplot of the difference in the amount of time students spent taking the exam from October to May for all students that participated in the ALEKS Group. This was found by subtracting the time it took each student to take the October exam from the time it took each student to take the May exam. The figure shows that many students took the May exam in less time, and this is shown by a negative time. The difference in exam time is one of four independent variables that will be used in the multiple linear regression.

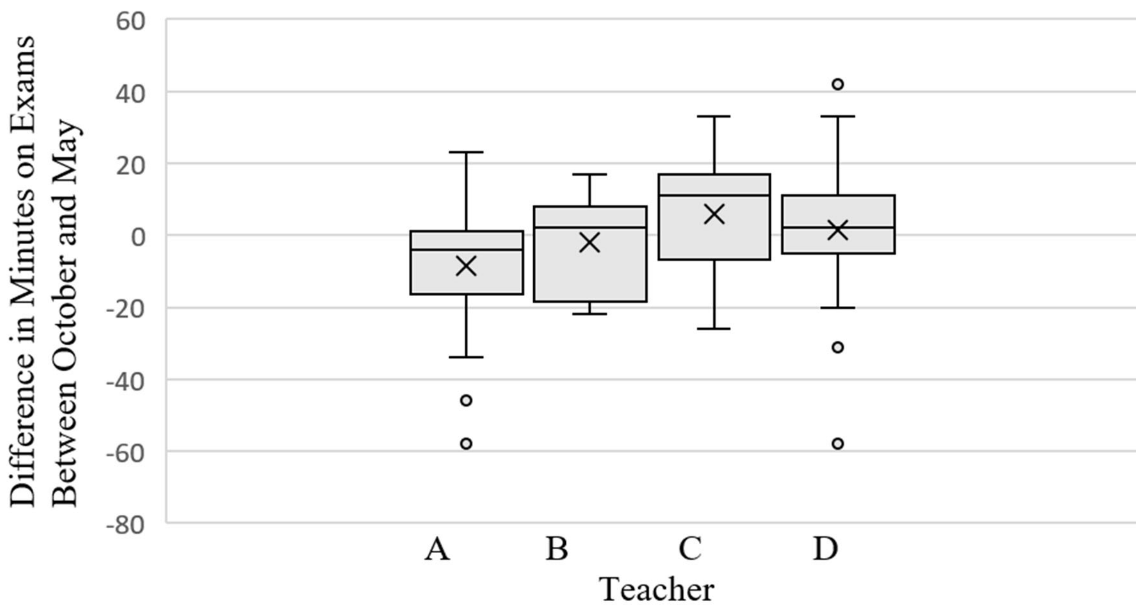

Figure 13. Boxplots of difference in exam time in minutes.

Figure 13 shows that the students taught by Teacher C had the greatest average difference in exam time with a positive mean and median difference. This means that students in this class on average took longer on the May exam than the October exam. All of the others experienced a negative or close to zero difference. Table 11 shows the descriptive statistics of the difference in exam time for all of the teachers in the ALEKS Group.

Table 11

Descriptive Statistics of Differences in Exam Time by Teacher

Teacher	*n*	Min	Max	Mean	*SD*
A	26	-58.000	23.000	-8.423	18.446
B	8	-22.000	17.000	-2.125	14.407
C	10	-26.000	33.000	5.800	17.008
D	29	-58.000	42.000	1.379	19.083

As shown in Table 11, the students taught by Teacher A, on average, decreased the amount of time spent on the May exam by 8.42 minutes. Conversely, the students in Teacher C's class increased on average by 5.80 minutes. The standard deviations are roughly the same for all classes, with two classes decreasing the average amount of time spent on the May exam and two classes increasing the amount of time.

Figure 14 shows the differences in the percentage of topics mastered separated by the teacher. This is found by subtracting the percentage of topics mastered at the beginning of the year from the percentage of topics mastered at the end of the year.

As shown in Figure 14, students taught by Teachers A, B, and C, all had similar means and medians for the difference in the percentage of topics mastered in the modules. Students taught by Teacher D on average mastered far fewer topics than all of the other classes. Table 12 shows the descriptive statistics for differences in modules mastered separated by the teacher. This was computed by subtracting the percentage of number of topics mastered in October from the percentage of number of topics mastered in May.

As shown in Table 12, the means of the difference of percentage of topics

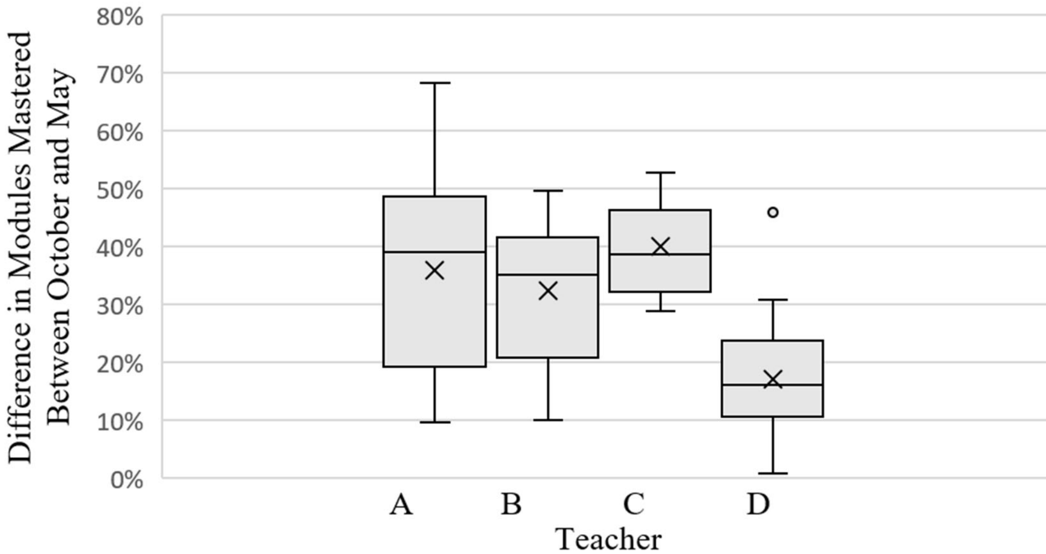

Figure 14. Differences in the percentage of topics mastered separated by teacher.

Table 12

Differences in Percentage of Topics Mastered from October to May by Teacher

Teacher	*n*	Min	Max	Mean	*SD*
A	26	10.000	68.000	36.039	17.224
B	8	10.000	50.000	32.500	13.234
C	10	29.000	53.000	40.200	7.800
D	29	1.000	46.000	17.172	9.864

mastered from October to May for students taught by Teachers A, B, and C, range from 33-40%, while those taught by Teacher D averaged 17%. This shows that students taught by Teacher D mastered about half the number of topics by the end of the year when compared with the other students in the ALEKS Group.

Figure 15 shows the amount of time students in the ALEKS Group were logged into the learning modules separated by the teacher.

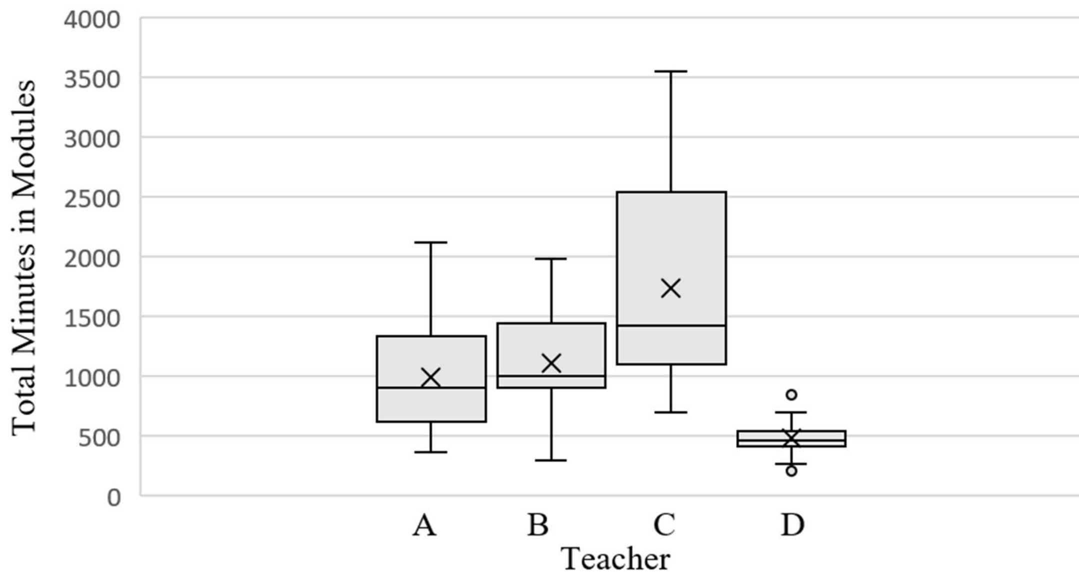

Figure 15. Number of minutes students spent logged into the learning modules.

As shown in Figure 15, students taught by Teacher D spent considerably less time logged in to the learning modules than students taught by the other teachers in the ALEKS Group. The students in Teacher C's ALEKS Group show a very large spread while the students in Teacher D's ALEKS Group had a very small spread. The students taught by Teachers A and B have very similar mean and median times spent logged into the learning modules. Table 12 shows the descriptive statistics for the amount of time students spent logged in to the learning modules separated by the teacher.

Table 13

Descriptive Statistics of Number of Minutes Students Spent Logged into the Learning Modules from October to May

Teacher	*n*	Min	Max	Mean	*SD*
A	26	364.000	2123.000	991.192	445.111
B	8	303.000	1988.000	1108.875	492.346
C	10	697.000	3557.000	1738.500	941.167
D	29	210.000	904.000	482.207	161.861

As shown in Table 13, students taught by Teacher D logged in to the modules less than half the number of minutes of any other ALEKS Group. The students taught by Teacher C averaged the most time with 1,738.5 minutes (almost 30 hours). Next were the students in Teacher B's class with 1,108.9 minutes (about 18.5 hours). Students taught by Teacher A logged in 991.2 minutes (about 16.5 hours) and students in Teacher D's class logged in 482.2 minutes (about 8 hours).

Next, the correlations between the variables will be shown (Table 14), then visualizations of bivariate relationships, using scatterplots, between the dependent variable and each independent variable will be shown.

Table 14

Correlations Between Variables for Students in the ALEKS Group

Variable	Diff. exam scores	Diff. exam time	Diff. module score	Module time
Diff. exam scores	-	.246*	.564**	.331**
Diff. exam time	.246*	-	.061	.052
Diff. module score	.564**	.061	-	.599**
Module time	.331**	.052	.599**	-

Note. Diff. = Difference; *p < .05, **p < .01.

As shown in Table 14, there is a weak positive correlation between difference in exam scores and difference in exam time, $r(71) = .246$, $p < .05$, and there is a strong positive correlation between the difference in exam scores and difference in module score, $r(71) = .564$, $p < .01$. There is also a moderate positive correlation between the difference in exam scores and module time, $r(71) = .331$, $p < .01$. This indicates that mastering more topics is strongly related to higher exam scores while spending more time in the modules is moderately related to higher exam scores.

Figure 16 shows the relationship between differences in exam scores and the difference in the amount of time spent on the exams.

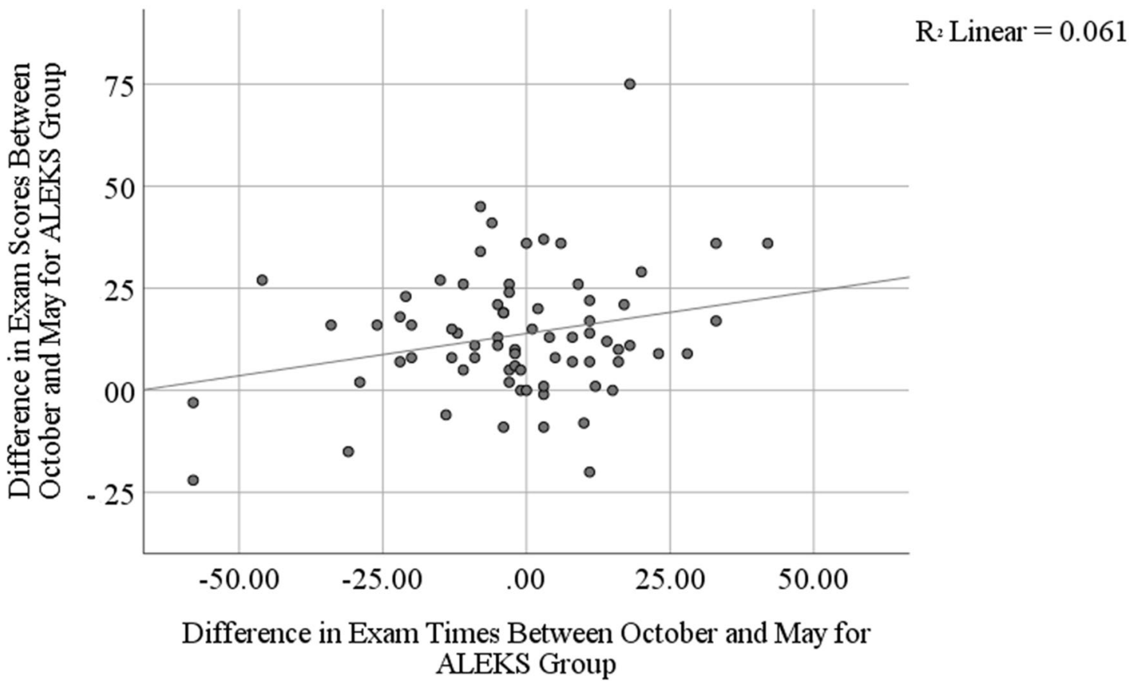

Figure 16. Scatterplot of the correlation between the difference in exam scores and difference in exam time for students in the ALEKS Group.

As shown by Figure 16, the correlation between the difference in exam scores and the difference in exam time for students in the ALEKS Group is very weak. This shows that 6.1% of the variance is being accounted for in the difference in exam scores from the difference in the amount of time students spent taking the exam. It is a small positive correlation.

Next, Figure 17 shows the relationship between differences in exam scores and the difference in the percentage of topics mastered.

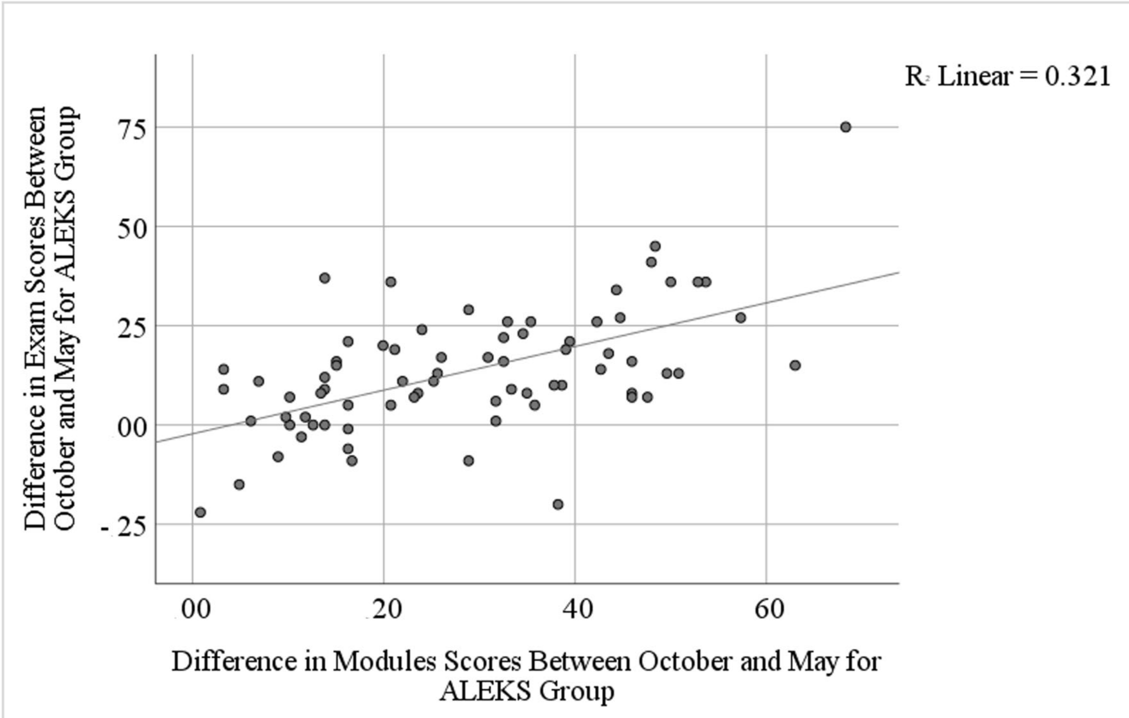

Figure 17. Scatterplot of the correlation between the difference in exam scores and difference in module scores for students in the ALEKS group.

As shown by Figure 17, there is a strong positive correlation between the difference in exam scores and the difference in module scores. This shows that 32.1% of the variance is being accounted for in the difference in exam scores from the difference in module scores. Overall, as students mastered more topics, their exam scores increased.

Figure 18 shows a scatterplot of the relationship between differences in exam scores and the amount of time spent in the modules. This accounts for all time logged into the modules only and should not be interpreted as time spent by students working in the modules.

As Figure 18 shows, there is a moderate positive correlation between the difference in exam scores and time spent logged into the modules for students in the

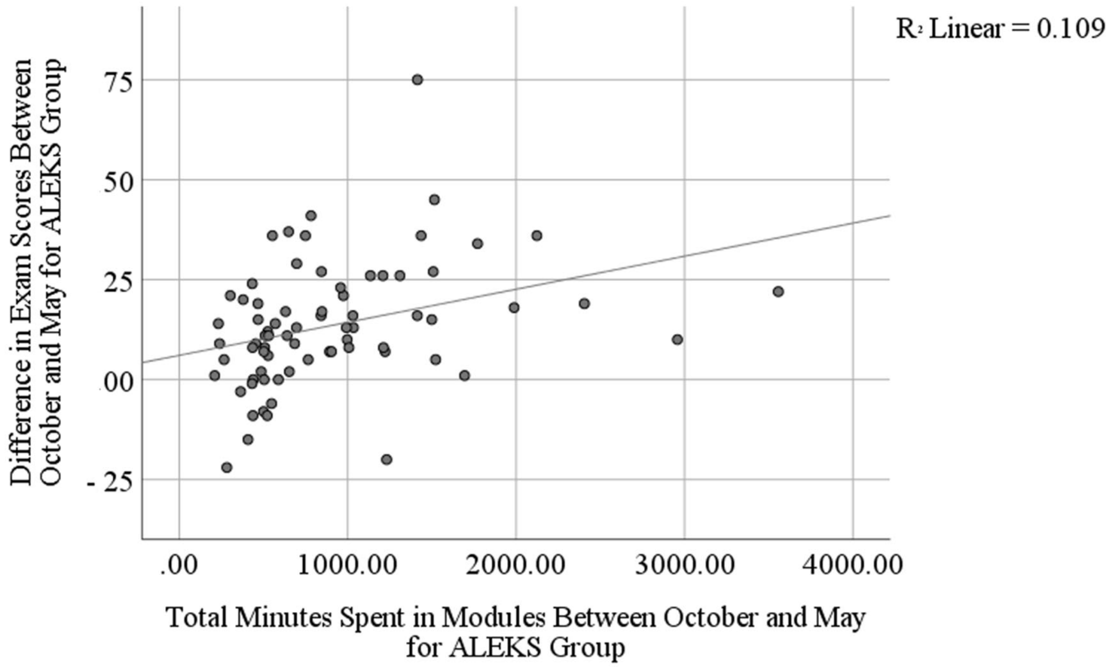

Figure 18. Scatterplot of the correlation between the difference in exam scores and time spent logged into the modules for students in the ALEKS group.

ALEKS Group. This shows that 10.9% of the variance is being accounted for in the difference in exam scores from the time spent in the modules. Only students who spent less than 600 minutes (10 hours) saw a decrease in exam scores from October to May, except for one student who saw a decrease at 1,231 minutes (about 20.5 hours). Only 12.3% of the students (*n* = 9) in the ALEKS Group had a decrease in exam scores from October to May.

To further examine this question, the researcher conducted a multiple linear regression analysis to investigate the potential factors that influenced students' growth on the ALEKS PPL Mathematics Placement Exam. It was hypothesized that differences in the amount of time spent taking the ALEKS Mathematics Placement Exam from October to May, the difference in the percentage of topics mastered in the ALEKS PPL Learning

Modules, the Teacher students were assigned to, and the amount of time logged into the ALEKS PPL Learning Modules would positively predict the difference in exam scores.

Results show that 39.1% of the variation in the difference of exam scores can be accounted for by the predictor variables, collectively, $F(6, 66) = 7.05$, $p < .001$. This analysis used the students in Teacher C's class as the reference category. Looking at the unique individual contributions of the predictors, the results indicate that the difference in exam time, $b = 0.22$, $t(1) = 2.54$, $p = .013$, and differences in module scores, $b = 0.49$, $t(1) = 3.83$, $p < .001$, positively predict differences in exam scores. The predictor variable of time spent in the modules did not have an effect on the difference in exam scores, $b < 0.01$, $t(1) = 0.52$, $p = .603$. Teacher A's students experienced a non-significant impact, $b = 9.10$, $t(1) = 1.67$, $p = .101$, along with Teacher B's and Teacher D's students, $b = 5.62$, $t(1) = 0.88$, $p = .382$, and $b = 5.98$, $t(1) = 0.95$, $p = .34$, respectively.

The results suggest that the factors of exam time and module mastery scores influenced ALEKS Group students' outcomes. Students who took more time on the May exam, compared to their October exam time, and who mastered more topics in the ALEKS PPL Learning Modules, scored higher on the ALEKS Mathematics Placement Exam at the end of the academic year.

CHAPTER V

DISCUSSION

The purpose of this study was to examine relationships between high school student's performance in the ALEKS PPL Modules and performance on the ALEKS College Mathematics Placement Exam. Students who participated in the ALEKS Group were assigned to work in the ALEKS PPL PreCalculus Learning Modules for 20 minutes each class period from October to May. The results of this study provide important insights on how the two groups of high school students performed on the ALEKS Mathematics Placement Exam after one group used ALEKS PPL PreCalculus Learning Modules.

The first two research questions examined factors and differences between the two groups' exam scores and the third research question examined factors that influenced exam scores within the ALEKS Group. This chapter discusses the results of each of the three research questions including discussions on how teacher implementation might have affected the outcome and provides recommendations for future use of Intelligent Tutoring Systems in high school settings.

How Assignment to ALEKS PPL PreCalculus Learning Modules Affected ALEKS Mathematics Placement Exam Scores

The results of the first research question showed a significant interaction between group (ALEKS Group or Non-ALEKS Group) and the date students completed the exam (October or May). The limitations of the study prevent the conclusion that assignment to the ALEKS PPL Learning Modules did affect student performance on the ALEKS Mathematics Placement Exam. One reason to consider the results with caution was the effect of Teacher E, who showed significant disengagement with the ALEKS program and this study.

A careful review of the results revealed that the students taught by Teacher E, who taught 74% of the Non-ALEKS Group, had similar scores on the October exam compared to all other classes. Conversely, those same students scored significantly lower on the May exam compared to all other classes, even other students in the Non-ALEKS Group. A closer examination showed that students taught by Teacher E spent far less time taking the May exam compared to the other groups of students. This could have been because Teacher E had the students in her class take the exam on the last day of the school year. Students are usually excited on the last day of the school year and they also know that their grades have already been determined by that point.

The results from the second research question showed that for every minute spent on the May exam, scores increased by about 4%. Students in the ALEKS Group may have felt more motivated to perform better on the exam than students in the Non-ALEKS Group because they had invested time in the program throughout the academic year or their teachers placed a grade value on their exam scores. The students in the Non-ALEKS Group did not have a grade value attached to their exam scores.

The students that worked with the ALEKS PPL PreCalculus Learning Modules experienced more growth on the ALEKS Mathematics Placement Exam than students in the Non-ALEKS Group. The students in the ALEKS Group had the opportunity to have individualized mathematics practice and also be exposed to the expected mathematics in the college curriculum. This allowed them to address the misalignment that is documented between high school and college mathematics (Barnett, Fay, Bork, & Weiss, 2013; Madison et al., 2015; Venezia et al., 2003).

The disconnect between high school mathematics and the mathematics colleges expect students to know (Barnett, Fay, Bork, & Weiss, 2013; Madison, et al., 2015; Venezia et al., 2003) became apparent when students were required to learn material for the ALEKS PPL Modules that students had not been taught in the high school. Teacher D reported that having students learn material that was not going to be covered in the class was a benefit of implementing ALEKS PPL into the classroom, while also expressing that it was frustrating to have students learn material that they had not planned to cover. This aligns with the NCPPHE and SREB (2010), which states that teachers are focused on their own state standards, and therefore, they do not want to spend extra time on material that is not a part of the curriculum. The implications of this show that implementing ITS into high schools can fill gaps in students' knowledge and cover mathematical concepts that are not in the curriculum. This can have a positive impact on college placement exam scores, and therefore, increase student's access to college-level mathematics upon graduation.

As a former high school mathematics teacher, I felt that covering all of the state core standards was challenging, given the amount of time I had to spend with the students. This detered me from teaching material that was not going to be on the standardized tests at the end of the year. It was also common for students to progress to the next mathematics course without mastering the prerequisite course. Unfortunately, students who failed Algebra I moved on to Algebra II with large gaps in their Algebra I knowledge. As a high school teacher, I was often unable to determine each student's gaps in mathematics knowledge. Having a program, like ALEKS, that provides the teacher with support in finding these gaps and teach students some of the basic topics they are missing could be benificial. Algebra is a very broad area of mathematics and there are many different areas where a teacher's focus could be placed. I have also taught many years in the remedial mathematics department at the local university and have wittnessed the disconnect in the mathematics taught in the high school and what is expected at the university.

Difference Between the ALEKS Group and Non-ALEKS Group in the Percentage of Students Ready for College Algebra

The results of the second research question showed that October exam scores were a predictor of scoring at least a 46% on the May placement exam. Students were 10% more likely to score at least 46% on the May exam for every 1% increase in their October exam score. Although Group was not a predictor of scoring at least 46% on the May exam, May exam time was a predictor. This showed that the more time students spent on the May exam, the higher the scores were to be expected. Providing students with adequate time to take the exam, and providing an incentive for student effort, was important for students to realize actual placement scores.

The ALEKS Group experienced a 43.8% placement rate while the Non-ALEKS

Group had an 11.1% placement rate. Two teachers (Teachers A and B) in the ALEKS Group had over 50% of their students place into College Algebra while Teachers C and D in the ALEKS Group had placement rates similar to Teacher F (29-31%) in the Non-ALEKS Group. Teacher E had only 5% of their students score high enough to place into College Algebra.

Furthermore, the Non-ALEKS Group showed that 89% of the students would place into remedial mathematics courses at their local university. This number was 56% for the ALEKS Group. This amounts to 33% fewer students taking remedial mathematics courses in college, saving potentially millions of dollars, and allowing more students to graduate. The results of this study align with the meta-analysis conducted by Steenbergen-Hu and Cooper (2013), which found that ITS has the potential to have positive effects on student learning. One year later, Steenbergen-Hu and Cooper (2014) found that college students experienced a larger effect from ITS compared to students who did not use ITS. Perhaps because these students are seniors, one year away from college, they experienced a more profound effect from ITS than those in the 2013 meta-analysis which focused on the K-12 population.

Factors that Influenced Student Outcomes

The results of the third research question showed that 39.3% of the variation in the difference of exam scores could be accounted for by the four predictor variables which included the difference in the amount of time spent taking the exams, the difference in module scores, the amount of time students were logged into the modules, and the teacher. Two of the four predictor variables, the difference in the amount of time spent taking the exam and the difference in module scores, proved to be significant in positively predicting differences in exam scores.

These results align with Fanusi (2015) who found that there was a correlation between the percentage of concepts completed in ALEKS and the score on the Georgia Criterion Referenced Competency Test (CRCT) mathematics achievement end-of-year test. In the present study, 32.1% of the variance in the difference of exam scores was accounted for by the difference in module mastery scores. The multiple linear regression did not find the time spent logged into the modules to be significant. This could be due to the inability of the program to account for time working directly with the modules and instead just recording time spent logged into the modules. Some teachers only required students to record a certain amount of hours logged into the program to receive credit, and previous research by Bartelet et al. (2016) found that students are generally not self-motivated to use ITS if it is not compulsory.

Additional insights were provided when the teachers reported to me on their implementation of the ALEKS program in their classrooms. The students taught by Teacher D had the smallest module score growth and also had the smallest exam score growth. This teacher expressed that ALEKS accounted for less than 10% of students' overall grade and was not consistent on how ALEKS was graded. Teacher D reported that they would decide if an individual student deserved credit or not based on their opinion of whether the student was putting in effort. This teacher also expressed that it was difficult to tell which students were using the program correctly, because some students would be logged in for a long time and not complete any modules, yet they were trying but were struggling with the topic. Conversely, other students could finish fifteen modules in thirty minutes. In Teacher D's classroom, there was not a set amount of time or modules to master to receive their grade. Teacher C reported that they consistently had ALEKS count as 10% of the students' overall grade and required the students to be engaged with ALEKS for a set time and to complete a certain amount of modules to receive credit. The students taught by Teacher C averaged the most minutes logged into the modules and also had the highest average difference in module mastery scores. These students also averaged the most time spent taking the placement exam in May compared to October, but they did not have the highest difference in exam scores. Teacher C was the teacher that I felt was most vested in the program. This teacher asked the district to allow them to use intelligent tutoring systems in their classroom prior to this study. I could tell that Teacher C was frustrated with the students' lack of interest in using the program. This teacher stated that students who put in the effort to use the program benefited from the program, while those that did not like using the program did not see as many gains in exam scores.

The students taught by Teacher A experienced the highest difference in exam scores. Ironically, this teacher had the lowest opinion of the ALEKS program. I had several interactions with Teacher A, who was adamant that the ALEKS program was difficult to use and that students would vocalize their dissatisfaction with the program. This teacher was also very stern with the students and would tell them that they had to do the program to get the 10% grade credit. Teacher A also said that many of the more vocal students ended up transferring out of the class before the end of the year, and therefore, their scores were not used in this study. The students taught by Teacher A, on average, spent more time taking the October exam than the May exam. They had the largest standard deviation in difference in module mastery scores, and although they were second in mean difference in module mastery scores, they did have the highest median in this category. Teacher A had students who did not have much growth at all (e.g., 9.8%), and then others that had large growth (e.g., 68%) in module mastery.

Teacher B had only eight participants in the class. This teacher expressed that the students were overall good students and not underachieving students. This teacher expressed that the students did not like working with the program and pushed back at Teacher B for requiring students to use it, making it more difficult for the teacher. Teacher B expressed that the students who used the program consistently showed improvement. Students were required to spend at least one hour per week in ALEKS or complete ten modules to receive credit. ALEKS accounted for 10% of their overall grade. Teacher B stated that, if students completed the one hour and did not complete any modules, then they would not receive credit for the week. As these reports of teacher implementation patterns show, the differences in implementing the ALEKS program had an important influence on the outcomes in this study.

In the present study, 6.1% of the variance in the difference of exam scores was accounted for by the difference in exam time between October and May. The teachers who taught the students in the ALEKS Group all used the May exam as part of students' grades, which could have motivated the students to spend a little more time and try harder on the exam. These results are consistent with the recommendation by the ALEKS Corporation to assign a grade value to the program to incentivize students to put forth more effort (Advanced Customer Solutions, ALEKS Corporation, 2017).

Most teachers reported to the researcher that implementing ALEKS into their classroom was easy and beneficial. In contrast, Teacher A, said they would not implement ALEKS PPL into their classroom ever again because there were too many problems with students forgetting passwords and not knowing how to gain access to the program. Teacher B expressed that filling gaps in students' knowledge through the use of ALEKS PPL benefited the students. Research by Karner (2017) found that students who used ALEKS in a remedial setting were able to close the gap between low achieving students and those who were not by 30.4%.

All teachers in the ALEKS Group reported to the researcher that they believed students benefited from the use of ALEKS PPL and that the students who used the program as instructed increased their May exam scores. The amount of time students spend working with technology can affect student outcomes. For example, Cheung and Slavin (2013) found that educational technology programs were more effective if they required more than 30 minutes per week when compared with those that were used less than 30 minutes per week. The ALEKS Corporation recommends using the program at least three hours per week for effective implementation (Advanced Customer Solutions, ALEKS Corporation, 2017). If teachers do not support the program, students are less likely to spend the recommended amount of time with the technology (Cheung & Slavin, 2013).

Recommendations

Based on the results of this study, implementing the use of ITS in conjunction with a regular mathematics high school course might be beneficial in increasing scores on the ALEKS College Mathematics Placement Exam. It is recommended that teachers are supported with the proper training and technology (such as a good internet connection and computers) so that in turn they will support ITS in their classroom. The minimum of three hours per week proposed by The ALEKS Corporation is recommended for students to achieve the benefits of ALEKS PPL. It is also recommended to incentivize students to use the program by placing a grade value towards the completion of modules.

Conversely, this study shows that placing a grade value on the amount of time spent in the modules was not as effective as placing a grade value on the completion of the modules. Students who mastered more topics had more growth on the exam than those who did not master as many topics, while students who spent more time logged into the program did not necessarily experience more growth on the placement exam. Furthermore, this study found that the amount of time students spent on taking the exam impacted results on the ALEKS Mathematics Placement Exam. It is therefore recommended that teachers provide students enough time (about 1 hour) for students to be able to finish the exam.

One of the problems this study found was that implementing ITS into a high school mathematics class can have its challenges. Motivating students to master topics is essential for students to realize the positive effects that ITS has to offer. The ALEKS Corporation (2017) and Cheung and Slavin (2013) both recommend that students spend sufficient time with the program in order to achieve the positive effects that ITS has to offer. One recommendation would be for the ALEKS Corporation to explore ways to better motivate students to complete the modules (e.g., gamification of the modules). Future research could examine how to effectively motivate students to spend the time needed to realize positive outcomes.

Conclusion

This study examined relationships between high school student's performance in the ALEKS PPL Modules and performance on the ALEKS College Mathematics Placement Exam. The results showed a statistically significant difference in exam scores between the ALEKS Group and the Non-ALEKS Group, with the ALEKS Group participants in this study having greater increases in performance on the ALEKS College Mathematics Placement Exam. The probability of placing into College Algebra was attributed to the initial score on the October placement exam and the amount of time students spent taking the exam in May. Students were 10% more likely to score at least a 46% on the ALEKS Mathematics Placement Exam for every 1% increase in their October placement exam score. However, the limitations discussed earlier, including the small sample size, non-randomized placement, testing effects, and lack of teacher engagement, need to be considered in the interpretation of these results.

The factors that influenced student outcomes on the ALEKS Mathematics Placement exam for those students assigned to the ALEKS Group included the amount of time spent taking the exam in May, the expectations of the classroom teacher, and the number of modules mastered. Students who spent more time taking the exam in May outperformed students who did not. Students who completed more modules scored higher on the May exam than those who did not. Students whose teachers required participation were more engaged with the modules and the exams. These results suggest that students who were motivated to complete the learning modules, and students who took the time to complete the exam, had better performance outcomes. If schools can effectively implement ALEKS into their current mathematics classrooms, there is the potential to strengthen students' preparation for college level mathematics. By increasing students' scores on the ALEKS Mathematics Placement Exam, students are potentially decreasing the likelihood of taking remedial courses in college.

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APPENDICES

Appendix A

Teacher Implementation Report

Teacher Implementation Report

1. How did you use ALEKS PPL in your class?
    a. When was the program used? (example; at the start of class or the end class)
    b. How much time were students allotted to use the program?
    c. What was the consistency of program use?
2. Do you feel that the amount of time that students spent on the program during class was appropriate?
3. How was ALEKS PPL implemented into the student's grade?
    a. If so, what percentage of their grade was ALEKS PPL?
    b. If so, how was their ALEKS PPL grade calculated?
4. Were there any technical issues with student accounts?
    a. If so, was it resolved and how long did it take?
    b. If so, what was your experience with getting the problem resolved?
5. What was the computer use like?
    a. Did the computers function properly?
    b. Did you have access to them when needed?
6. Did you experience any benefits with using ALEKS PPL in your classroom?
7. Did you experience any inconveniences with using ALEKS PPL in the classroom?
8. Do you feel that your students experienced any benefits with using ALEKS PPL?
9. Do you feel that your students experienced any negative effects with using ALEKS PPL?
10. The goal of implementing ALEKS PPL into your mathematics course was to help your students be better prepared for placement into college algebra. Was this goal achieved? Why or why not?
11. Please explain any situations that you believe affected your students' outcome data. For example, did students transfer into the class from a higher level courses or did students relay information to you that might affect their student outcomes?
12. Are there any other comments that you would like to add about using ALEKS PPL in your classroom?

Appendix B

IRB Permission Letter

Thursday, September 6, 2018 at 3:06:37 PM Pacific Daylight Time

Subject: Approval letter from USU IRB
Date: Thursday, September 6, 2018 at 3:05:50 PM Pacific Daylight Time
From: noreply@usu.edu
To: Patricia Moyer-Packenham, jen_n_mat@msn.com

UtahState University
OFFICE OF RESEARCH AND GRADUATE STUDIES

Institutional Review Board

USU Assurance: FWA#00003308

Expedite #7

Letter of Approval

FROM:

Melanie Domenech Rodriguez, IRB Chair

Nicole Vouvalis, IRB Administrator

To:	Patricia Moyer-Packenham, Jenny Nehring
Date:	September 06, 2018
Protocol #:	9350
Title:	A Comparison Study Of High School Seniors To Determine The Impact Of Aleks Prep Modules On Th College Mathematics Placement Exam
Risk:	Minimal risk

Your proposal has been reviewed by the Institutional Review Board and is approved under expedite procedure #7 (based on the Department of Health and Human Services (DHHS) regulations for the protection of human research subjects, 45 CFR Part 46, as amended to include provisions of the Federal Policy for the Protection of Human Subjects November 9, 1998):

> Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.This approval applies only to the proposal currently on file for the period of one year. If your study extends beyond this approval period, you must contact this office to request an annual review of this research. Any change affecting human subjects must be approved by the Board prior to implementation. Injuries or any unanticipated problems involving risk to subjects or to others must be reported immediately to the Chair of the Institutional Review Board.

This approval applies only to the proposal currently on file for the period of one year. If your study extends beyond th approval period, you must contact this office to request an annual review of this research. Any change affecting hum subjects must be approved by the Board prior to implementation. Injuries or any unanticipated problems involving ri to subiects or to others must be reported immediately to the Chair of the Institutional Review Board.

Prior to involving human subjects, properly executed informed consent must be obtained from each subject or from authorized representative, and documentation of informed consent must be kept on file for at least three years after the project ends. Each subject must be furnished with a copy of the informed consent document for their personal records.

CURRICULUM VITAE

JENNY NEHRING

1562 N 600 W
Pleasant Grove, UT 84062
801-888-5917
Jenny.Nehring@uvu.edu

EDUCATION

Utah State University
Ph.D. Education **2021**
Specialization: Curriculum and Instruction
Concentration: Mathematics Education and Leadership

Western Governors University
M.S. in Mathematics Education **2012**

Utah Valley University
B.S. Mathematics **2005**

Utah Valley University
B.S. Mathematics Education **2005**

AWARDS AND PROFESSIONAL RECOGNITION

Outstanding Instructor, Utah Valley State College
TRIO Student Support Services **2007**
Outstanding Score on Principles of Learning and Teaching, ETS Praxis **2008**
Outstanding Score on Mathematics: Content Knowledge, ETS Praxis **2009**

UNIVERSITY TEACHING EXPERIENCE

Adjunct Instructor – Strategic Management and Operations **2019-present**
Utah Valley University, Orem, UT
Collaborated on building the syllabus, exams, overall
course structure.

Lecturer – Finance and Economics **2015 - 2017**
Utah Valley University, Orem, UT
Collaborated on building the syllabus, exams, overall

course structure, and administered all grades. Developed
a hybrid course for MGMT 2240.

Adjunct Instructor – Mathematics **2005 – 2015**
Utah Valley University, Orem, UT
Developed syllabus and overall course structure and
administered all grades.

PUBLIC SCHOOL TEACHING EXPERIENCE

Mathematics Teacher – Algebra 2, Precalculus, College prep, College Algebra **2007 – 2014**
American Fork High School, American Fork, UT
Collaborated on curriculum and exam implementation
and administered all grades. Designed and implemented
a new course to prepare students for college algebra.
Implemented and taught concurrent enrollment college
algebra.

Mathematics Teacher – Pre-Algebra, Algebra **2005 – 2006**
Mountain Ridge Junior High, Highland, UT
Collaborated on curriculum and exam implementation,
and administered all grades

RESEARCH INTERESTS

- Mathematical assessment programs
- Mathematics placement
- Intelligent tutoring systems
- Online teaching

PRESENTATIONS

Moss, D, & Nehring, J. V. (2019, October). *Supporting students in understanding fractions: Fractions are more than parts and wholes*. Presentation conducted at the National Council of Teachers of Mathematics (NCTM) Regional Conference, Salt Lake City, UT.

Moss, D, & Nehring, J. V. (2019, October). *Using discussion to make sense in a mathematics classroom*. Presentation conducted at the National Council of Teachers of Mathematics (NCTM) Regional Conference, Salt Lake City, UT.

Nehring, J. V., & Mgonja, T. (2016, November). *What does engaged learning look like?* Presentation conducted at the Annual Conference of the Utah Council of Teachers of

Mathematics (UCTM), Salt Lake City, UT.

SERVICE AND INVOLVEMENT

- Classroom volunteer for 1st-grade mathematics at Manila Elementary (2017-2018)
- Designed and implemented a hybrid course for MGMT 2240 Business Calculus (2017)
- Faculty Advisory Group member for UVU Competency-Based Education (2015-2016)
- Committee member for textbook adoption for Alpine School District's college prep mathematics course (2009)

GUEST LECTURES

Guest Lecture, MAT 1010 Intermediate Algebra (for Thomas Mgonja) (2018, February)
Guest Lecture, MAT 1010 Intermediate Algebra (for Ashlee Barker) (2018, November)

UNIVERSITY TEACHING

Utah Valley University, Orem, Utah (2005-present)

Courses Taught-Utah Valley University
MGMT 2340 – Business Statistics I
Presents an application of statistics in business and economics covering methods of collecting, analyzing, and presenting data. Includes frequency distributions, averages, index numbers, probability, sampling, estimation, analysis of variance, time series, regression and correlation, and chi-square.

MGMT 2240 – Business Calculus
Studies quantitative tools, which aid in decision making. Teaches business specific use of calculus, algebra, and introductory statistics, plus emerging non-linear mathematics (chaos) in business. Uses lectures, videos, online quizzes, online discussions, online tutoring, and problem sets to explain concepts.

MATH 1100 – Introduction to Calculus
Introduces the student to differential and integral calculus with applications to a variety of fields, including business, economics, and the life, social, and physical sciences. Develops and applies the concepts of calculus to functions of one variable. Studies differential calculus involving functions of several variables. Emphasizes understanding and communication of mathematical ideas, logical reasoning, and problem-solving.

MATH 1060 – Trigonometry
Includes the unit circle and right triangle definitions of the trigonometric functions, graphing trigonometric functions, trigonometric identities, trigonometric equations,

inverse trigonometric functions, the Law of Sines and the Law of Cosines, vectors, complex numbers, polar coordinates, and rotation of axes.

MATH 1050 – College Algebra
Includes inequalities, functions and their graphs, polynomial and rational functions, exponential and logarithmic functions, conic sections, systems of linear and nonlinear equations, matrices and determinants, arithmetic and geometric sequences, and the Binomial Theorem.

MAT 1030 – Quantitative Reasoning
Introduces major topics in the field of mathematics. Includes sets, algebra, geometry, and statistics. Emphasizes problem solving and critical thinking.

MAT 1010 – Intermediate Algebra
Expands and covers in more depth basic algebra concepts introduced in Beginning Algebra. Topics of study include linear and quadratic equations and inequalities, polynomials and rational expressions, radical and exponential expressions and equations, complex numbers, systems of linear and nonlinear equations, functions, conic sections, and real world applications of algebra.

MAT 0990 – Introductory Algebra
For students who have completed a minimum of one year of high school algebra or who lack a thorough understanding of basic algebra principles. Teaches integers, solving equations, polynomial operations, factoring polynomials, systems of equations and graphs, rational expressions, roots, radicals, complex numbers, quadratic equations, and the quadratic formula. Prepares students for MAT 1010, Intermediate Algebra.

MAT 0950 – Foundations for Algebra
Designed for students requiring basic math and pre-algebra instruction. Covers basic operations for number systems up to and including real numbers. Includes fractions, ratios, proportions, decimals, exponents, roots, linear equations, and polynomial expressions.