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Does ALEKS Help with Mathematical Retention as Measured on the ACT

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Does ALEKS Help with Mathematical Retention as Measured on the ACT

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The thesis entitled '**Does ALEKS Help with Mathematical Retention as Measured on the ACT**' presented by **Pamela S. Waits**, a candidate for the degree of **Master of Science in Mathematics,** has been approved and is worthy of acceptance.

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ABSTRACT

The purpose of this study was to examine the effects of a three tier ALEKS program on the retention of mathematical knowledge as assessed on the student's ACT math score. In recent years, ACT has noted a decrease in student readiness for college level math courses and the need for more students to be placed in a remedial math course. Starting the 2019-2020 school year students at Pickerington High School North were enrolled in a three tier ALEKS program that consisted of High School Prep, Algebra Review, and then their content course. All juniors in the State of Ohio were given the ACT at the end of February. The results of the senior's math ACT scores, administered when they were juniors without the use of the three tier ALEKS program, were compared to the results of the current junior's math ACT scores with the use of the three tier ALEKS program for students at Pickerington High School North.

The results of this study indicated that the use of ALEK did increase a student's math ACT score, however a student's initial exposure of algebra and geometry, as assessed by the end of course AIR assessments, played a significant role in a student's math ACT score and cannot solely be replaced with the use of ALEKS. The study also indicated the minutes a student spent in ALEKS has a positive moderate correlation to the student's math ACT score. The linear model suggests that a student who works persistently in ALEKS for sixty minutes a week from the start of the school year to the administration of the ACT can raise their math ACT score by three points. While the study indicates that ALEKS does help in retention and an increase of mathematical knowledge additional studies will need to be conducted on a wider range of school districts and on other high stakes test such as state end of course assessments.

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CHAPTER I: INTRODUCTION

The purpose of this chapter is to present the background and statement of the problem, primary research questions along with the hypothesis, and the research design.

When asking students which class they struggle with the most, math is often echoed by many students. (Saad, 2018) Why is this, math is very straight forward two plus two will always equal four, and in most cases, in math, there is only one right answer, however when you examine the amount of material students are required to learn in math compared to other core subjects, the difference is tremendous. According to The State of Ohio Department of Education website (www.education.ohio.gov) The State of Ohio uses a framework for the required standards based off common core, within high school algebra there are forty-three unique standards required to be taught and within high school geometry there are forty-six unique standards required to be taught, in addition there are hundreds of unique mathematical standards taught prior to high school, which is much different than the other core subject areas. In science and social studies there are eight to sixteen unique standards taught each year, and in English there are four core focuses taught throughout all grades, the level of depth is just increased within each year. ("Ohio's Learning Standards for Mathematics")

The mathematical skills and standards taught from kindergarten through twelfth grade are fundamental skills as most jobs encompass some form of math, such as video game designers, animators, agriculturalists, and tradesmen such as plumbers and electricians. (Zurko & Westfield) With over three hundred standards listed on The State of Ohio Department of Education website for kindergarten math through high school geometry, typically a tenth-grade class, it is understandable that some students are not

grasping each and every standard, and as a result gaps are forming in their mathematical knowledge. ALEKS, Assessment and Learning in Knowledge Spaces, is a mathematical adaptive learning program designed to address the needs of students, by identifying and helping to fill in the gaps in a student's mathematical knowledge. ("What is ALEKS?") ALEKS is being implemented in schools across the country, including Pickerington Local Schools, in an effort to fill in mathematical gaps and increase standardized test scores. An analysis of district ACT scores, pre and post the implementation of ALEKS, will determine whether or not ALEKS is closing the gap and helping students leave high school better prepared for college level mathematics. Pickerington High School North is located in Pickerington, Ohio, a suburb of Columbus, Ohio. According to The State of Ohio school report card, Pickerington High School North is a diverse school with 22.1% African Americans, 6% Multiracial, 5.9% Hispanic, and 4.2% Asian or Pacific Islander. In addition, the population consists of 25% economically disadvantaged, 12.1% students with disabilities, and 3.4% are English Language Learners. ("School Report Card")

Background of the Problem

In recent years, the gap in mathematical knowledge is becoming extremely prevalent in standardized test scores. The ACT, a college entrance exam, used by most universities analyzed the math ACT scores of the 2019 high school graduates and concluded only 39% of the students are ready for college level math course work, this is a decline from 42% in 2015 (act.org). Nationwide every year forty to sixty percent of college students are required to enroll in remedial math courses as they are not prepared

and ready for college level mathematics courses. (Jimenez, Sargrad, Morales, & Thompson, 2016).

ALEKS, an adaptive learning software, is not just being implemented in elementary and high schools across the nation, but it is also being implemented in colleges and universities across the nation. (aleks.com) The ALEKS website points to eight different case studies across the United States in which the implementation of ALEKS at the college/ university level has increased mathematical knowledge and reduced the number of remedial math courses needed. One case study out of Utah Valley University noted that many of their students take two years off for religious studies. These students, upon returning, often found themselves needing to take remedial math courses as they had not been exposed to many of the mathematical concepts being assessed in the placement test for a few years. Utah Valley University implemented a 1 credit hour course known as Math100R where students work in an ALEKS preparation course, the course concludes with their math placement exam. As a result, Utah Valley University, noted that many students have eliminated at least one four to five credit hour mathematical course they are required to take, resulting in the students saving money and time towards their degree. Much like the students of Utah Valley University, high school students have had a gap in time for much of the material assessed on the ACT, as Utah Valley University found a refresher of the mathematical content assisted their students in being successful on the mathematical placement test. ("Research and Case Studies") Another study was conducted at the University of Kentucky in which students with an ACT math score below 30 are placed in an ALEKS PPL (placement, prepared, learning) program where they have also seen a decrease in the number of students that need

remedial math courses from 20% to 11%. ("Research and Case Studies") While these cases, which are provided on the ALEKS website are at the college or university level, similar results may reasonably be expected when preparing students in a high school setting.

Motivation for the Study

All high school students, who are not currently enrolled in a CCP, college credit plus, or an AP, advanced placement, math course are required to participate. Students begin in a high school prep course, which consists of pre-algebra and beginning algebra skills. Once students have mastered 70% of the content, they move to the second course, an algebra review course, which includes key algebra skills along with coordinate geometry skills. Again, once a student has mastered 70% of the content they are moved to their final course, for the juniors it is their content course, Algebra II. Within this course the juniors will practice advanced algebra skills along with trigonometric skills. All juniors will then take the ACT on February 25th, the district is hoping the implementation of the three tiered ALEKS program will help their students bridge the gap on retention of previously learned material, and as a result the district will see an increase in ACT math subscores. ACT math subscores for current seniors who did not use ALEKS will be compared to ACT math subscores for the experimental group.

Statement of the Problem

According to a report released by ACT (act.org) the ACT math benchmark for college readiness is a 22, with a three percent decline over the last four years. The ACT

tests the student's mathematical knowledge in six categories, pre-algebra, elementary algebra, intermediate algebra, coordinate geometry, plane geometry, and trigonometry, thus essentially testing a student's retention of mathematical content from 7th grade through 11th grade. (act.org) With such a wide range of content, encompassing over one hundred and fifty unique standards it is clear students are forming gaps within their mathematical knowledge. Numerous artificial intelligent mathematical programs, such as ALEKS, are being created by curriculum resource companies with the promise of identifying individual student needs and providing individualized curriculum that will bridge the gap on the retention of previously learned material and is assessed on high-stakes nationally recognized achievement test, such as the ACT.

Purpose of the Study

The purpose of this study is to examine whether ALEKS, (Assessment and Learning in Knowledge Spaces) is as effective in the high school setting as it has been shown in the college setting. In addition is ALEKS able to help bridge the gap on retention of previously learned material as assessed on the ACT.

All current juniors enrolled at Pickerington High School North, that are not currently enrolled in a CCP, College Credit Plus, math course or an AP, Advanced Placement, math course are required to participate in a three tier ALEKS program. Students begin in a high school prep course, which consist of pre-algebra and beginning algebra skills. Once students have mastered 70% of the content, they moved to the second course, an algebra review course, which includes key algebra skills along with coordinate geometry skills. Once a student has mastered 70% of the content they are moved to their

final course; for the juniors, it is their content course, Algebra II. Within this course the juniors will practice advanced algebra skills along with trigonometric skills. All juniors will then take the ACT on February 27th. The current seniors at Pickerington High School North that were enrolled in Algebra II, Pre-calculus, or Statistics last year would also be included in the study as the control group. Students who have little gaps in their mathematical knowledge, and thus less need for ALEKS, are typically enrolled in CCP and/or AP courses as they are advanced in their math skills; these students are not included in this study. The students included in this study tend to struggle with retaining previously learned mathematical content. An analysis of the seniors (control group) and juniors' (experimental group) math ACT scores would be analyzed to see if there was an improvement in the overall math ACT score with the implementation of ALEKS.

Significance of the Study

As math ACT sub scores continue to decline, and thus ACT college readiness scores, along with an increase of students being placed in remedial math courses in college it becomes apparent, students are not retaining all key mathematical content they are taught from as early as 7th grade on. Assessing the impact of the three tier ALEKS program on improving ACT scores could lead to a better understanding of how best high schools can help students progress through the required high school mathematical content while also helping them retain previous mathematical knowledge. While results may not generalize to all high schools the results may show improvements for Pickerington High School North as students prepare for the ACT and serve as a motivation to study

ALEKS' effectiveness at other high schools and/or lead to bigger, broader studies on ALEKS.

Primary Research Question

ALEKS is designed to be an adaptive learning system that creates an individualized curriculum to help students bridge the gap on retention of previously learned material in preparation for the ACT. With examining ALEKS effectiveness this study seeks to answer the following questions:

1. Will statistically significant differences emerge in mean math ACT sub scores for students at Pickerington High School North who did not use ALEKS to prepare for the math portion of the ACT when compared with students who did use ALEKS to prepare for the math portion of the ACT when controlling for results from the AIR math test?

2. Will minutes spent on ALEKS correlate significantly with the math ACT sub score?

Hypothesis

1. While controlling for previous math ability, as assessed on the AIR algebra and AIR geometry test, ACT sub scores will be higher for the experimental group (students who use ALEKS to prepare for the math ACT sub-test) than the control group (students who did not use ALEKS to prepare for the math ACT sub-test).

2. Hours spent on ALEKS will be highly correlated with ACT math sub scores.

Research Design

The study will include juniors and seniors at Pickerington High School North. There are roughly 445 seniors and 425 juniors currently attending Pickerington High School North, all juniors and seniors that were not enrolled in AP Calculus, AP Statistics, or a College Credit Plus Math course their junior year at Pickerington High School North. These students will be included in the study. Students who were enrolled in an AP math course and/or a CCP math course were not enrolled in ALEKS and thus they will not be included in the study.

The study will include AIR results in Algebra and Geometry along with ACT math scores. AIR test are designed by the American Institute of Research and utilized by The State of Ohio to assess student learning of the mathematical content starting in 3rd and tested annually through geometry, typically a 10th grade course. ("Ohio's Learning Standards for Mathematics") The data will be cleansed and received from administration in two excel documents, one for graduating class of 2020 (current seniors) and one for the graduating class of 2021 (current juniors), including the following variables: AIR algebra score, AIR geometry score, their math ACT score, and for the graduating class of 2021 the number of hours they spent in ALEKS. Students included in this study will not be identifiable from the final data set. ANCOVA and regression techniques will be used to examine the data, with AIR scores serving as a covariate to determine a student's baseline achievement in mathematics. This will help ensure the graduating classes of 2020 and 2021 are mathematically equivalent in their knowledge and we do not have a confounding variable of one graduating class being more gifted within mathematics than the other graduating class. The math ACT scores are examined to determine if the

graduating class of 2021 collectively improved over the math ACT scores of the graduating class of 2020. In addition, regression techniques will be implemented to predict the math ACT sub score from the hours spent in ALEKS controlling for baseline math achievement using results from the AIR test given in algebra and geometry.

Theoretical Framework

Students on average lose 27% of the mathematical content they learned from the previous year. (Kuhfeld, et al., 2018). The brain is composed of a network of neurons, which holds the content and knowledge a person has obtained. (Cherry, 2019) When students are first exposed to a new standard their understanding is very trivial and as a result the network of neurons retaining the information is very small and weak. As students continue to learn and practice the material and connect it to other previously learned topics the network of neurons becomes stronger and larger and it is more likely for the neurons, thus the student, to be able to recall the content in the future. (Cherry, 2019)

Many students do well at learning new standards and converting the material into their working memory, and as a result have success on short term assessments such as quizzes or chapter tests. However, students do not always convert their working memory to long term memory when the unit is over. (Cragg, Richardson, Hubber, Keeble, & Gilmore) Spaced repetition, the design of repeating material over a span of time, has shown to create a longer lasting understanding and comprehension of the material, as one has to retrieve the information from their memory thus strengthening the neurons which

stores the information. (Kang) In addition to spaced repetition, variations in the types of questions, such as direct computation, visual diagram, and real world application, increase the students understanding and overall long term knowledge of the material. (Lomibao, 2017)

Assumptions, Limitations, and Scope

To examine the effectiveness of ALEKS in preparing students to take the math ACT, the juniors who are enrolled in ALEKS must be diligent in completing their topics in a timely manner and on their own, without the assistance of equation solving apps and/or websites. All juniors have been given a goal of 60 minutes a week on ALEKS; however, some teachers are finding not all students complete their ALEKS requirement. As a result, teachers are implementing a weekly grade for ALEKS completion with the anticipation and hope that more students will complete their weekly ALEKS assignments. Unfortunately, some students do not complete their weekly ALEKS assignments, so they are assigned lunch detentions and/or Academic Study Times (AST) after school for the student to work on their ALEKS. Hopefully this implementation will encourage the juniors to be diligent in keeping up with their weekly ALEKS goal. In addition, twice a quarter students are given a knowledge check, which counts as a test grade, to assess the topics they have learned and to ensure they are genuinely learning each topic and retaining the information learned. These measures were put in place by the district as the juniors' willingness and desire to be diligent within the ALEKS program is critical to its success and an accurate analysis of its benefits.

While Pickerington High School North, demographically, is similar to many of the suburban schools in the Columbus, Ohio area, this study may not resemble all school districts across the United States, and thus the results may not be the same for all school districts. In addition, Pickerington Local School District is a one – to – one district in which all students have a chromebook, providing them easy access to ALEKS. Districts where technology is not as readily available may not be able to implement ALEKS to the same extent, and thus may have different results.

Definitions of Terms

AIR – (American Institute for Research) the designers of the State of Ohio standardized test in both algebra and geometry

ALEKS – (Assessment and Learning in Knowledge Spaces) a mathematical adaptive learning program designed by McGraw Hill.

ANCOVA – (analysis of covariance) is a test that controls for the covariate while examining the mean difference in the dependent variable

AP – advanced placement, college level coursework outlined and assessed through College Board.

CCP – college credit plus, a college credit bearing course taught through a local university to high school students

Knowledge Space Theory – using what a person knows and has mastered you can define a set of elements in which a person has the skills and prerequisite knowledge to learn

Summary

The purpose of this chapter is to present the background and statement of the problem, primary research questions along with the hypothesis, and the research design.

Math teaches fundamental skills utilized in most careers. With the advancements in technology around the world, The United States Department of Education ("Science, Technology, Engineering, and Math, including Computer Science"), notes the importance and need for strong mathematical and problem solving skills is only increasing, however each year, the ACT is finding, high school graduates readiness for college level math is decreasing (act.org).

A clear gap is forming between the mathematical skills high school students are retaining and the skills they need in order to be successful in the math subsection of the ACT, which is often used as an admissions criterion for college. ALEKS, an adaptive learning software, is being implemented in schools and universities across the country to help students fill in gaps in their mathematical knowledge. Pickerington Local Schools is implementing a three tier ALEKS program in which students will begin in a high school prep course, which consist of pre-algebra and beginning algebra skills. Once students have mastered 70% of the content, they move to the second course, an algebra review course, which includes key algebra skills along with coordinate geometry skills. Again, once a student has mastered 70% of the content they are moved to their final course, for the juniors it is their content course, Algebra II. Within this course the juniors will practice advanced algebra skills along with trigonometric skills. All juniors across the State of Ohio, as part of an initiative to increase high school graduates going to college, will take the ACT in February/March of 2020.

CHAPTER II: LITERATURE REVIEW

The purpose of this chapter is to examine retention studies, the effects of remedial math on students, and the ability for ALEKS to help with retention in both college mathematical courses and middle/high school mathematical courses.

Students on average lose 27% of the mathematical content they learned from the previous year. (Kuhfeld, et al., 2018). As a result, teachers spend numerous weeks, at the start of the school year, reviewing previous content before diving into the content for that academic year. The loss of content creates a mathematical gap in the student's ability, this gap is compounded when other factors such as socioeconomic status and race are examined. (Bol, 2005)

As students struggle to retain mathematical content colleges are seeing an increase in students being placed in remedial math courses. Nationwide every year an average of forty to sixty percent of college students are required to enroll in remedial math courses. (Jimenez, Sargrad, Morales, & Thompson, 2016). Students often get discouraged in remedial courses as they are time consuming and often delay a student's progress towards graduation, in addition remedial courses are costly as students are required to pay the per credit hour cost for the course, even though the course is not credit bearing. (Hanford, 2016)

In an effort to minimize the need for remedial math courses, many colleges are utilizing adaptive learning software to assist or replace remedial courses. (Ekowo, 2018) Adaptive learning software screens the student through a pre-assessment and then creates an individualized curriculum based on the student's needs. (Wall, 2020) While adaptive learning software may be a solution for many students, Wall points out that students who

have large gaps in their knowledge or students who lack independent study skills, may struggle in the adaptive learning environment where the design is individualized and self-paced. (Wall, 2020)

Retention Studies

Forty-one states have adopted the common core standards for mathematics. (corestandards.org) According to the common core website, thirty to forty-five knew mathematical standards are taught each year with students learning over three hundred mathematical standards by time they complete geometry. (corestandards.org) With the vast number of standards many teachers are looking for ways to help students retain the material from year to year.

The effects of repetition along with variation of practice was studied with a group of tenth grade students in which the control group was given sample problems to complete similar problems to those taught that day in class, whereas the experimental group was given a sampling of problems, some which were taught in previous lessons, while others required critical thinking as they were variations of the standard being taught, and yet other included diagrams or real world applications. In the study, Lomibao found, the students who were in the experimental group performed well above the students in the control grouping when taking a comprehensive unit test, leading to the conclusion that repetition and variation allowed for better retention of the material for the students. (Lomibao, 2017)

In a similar study conducted by Kang, spaced repetition was studied were students were given twelve practice problems each night. The students in the control group were given twelve problems containing only material from that day's lesson, whereas the students in the experimental group were also given twelve practice problems, but only the first four pertained to that day's lesson, the other eight questions were from pervious lessons. Two weeks after the final assignment was given students took an assessment to test their retention of the material. The students in the experimental group outperformed the students in the control group concluding that spaced repetition allowed for the students to gain a longer and deeper understanding of the material. (Kang)

Both studies on the effects of retention with varied practice provide promising results on teacher given assessments, however nationally students are still struggling when it comes to state standardized testing. In 2019 only thirty-four percent of eighth grade students performed proficient or above on state standardized test, nearly unchanged from the previous decade. (Richards, 2019)

Remedial Math in College

According to a report released by ACT (act.org) the ACT math benchmark for college readiness is a 22, with a three percent decline over the last four years. The ACT tests the student's mathematical knowledge in six categories, pre-algebra, elementary algebra, intermediate algebra, coordinate geometry, plane geometry, and trigonometry, thus essentially testing a student's retention of mathematical content from 7th grade through 11th grade. (act.org) Students that do not meet the Act benchmark for college

readiness in mathematics, or who do not score high enough on the colleges internal placement exam are often placed in remedial math courses. (Hanford, 2016)

Nationwide every year an average of forty to sixty percent of college students are required to enroll in remedial math courses. (Jimenez, Sargrad, Morales, & Thompson, 2016). The percentages are even more startling when we consider socioeconomic status and race. (Vandal) In 2015, of the students enrolled in a two-year community college, sixty nine percent of Pell Grant recipients, those receiving tuition assistance based on financial need, were required to take remedial math, seventy percent of African American students were required to take remedial math, whereas only fifty-three percent of Caucasian students were required to take remedial math. The number of students needing remedial math at a four-year college or university were slightly better, but still alarming. At a four-year institution thirty-seven percent of Pell Grant recipients, forty-four percent of African American students, but only twenty-three percent of Caucasian students required a remedial math course. (Vandal) While remedial math courses are designed to help students gain the necessary knowledge needed to be successful in credit bearing courses, many students get discouraged being placed in remedial classes as they feel underqualified for college. (Hanford, 2016) In addition to the demoralizing effects of being placed in a remedial course, students are also discouraged as it often increases their time in college and cost additional money. As a result, in 2015 at two-year community colleges, only eleven percent of African American completed their remedial work, nineteen percent of Pell Grant recipients, and twenty-three percent of Caucasian students completed their remedial coursework. (Vandal)

Adaptive Learning

Adaptive learning programs assess the students current academic level and then creates an individualized plan for the student, allowing them to work at their own pace through content they are cognitively ready to learn. Once a student has displayed mastery of a standard additional topics may be opened that is now within their cognitive ability. (Griff & Matter, 2013) In addition, adaptive learning software provides instant feedback to students. If a student gets a problem wrong, they are walked through the correct steps to answer the question and then provided with a similar problem to help them practice. When the student answers a question correctly, they are given positive encouragement which provides a sense of accomplishment and motivation for the student to continue. (Falloon, 2010)

Colleges utilizing ALEKS

The ALEKS website points to eight different case studies across the United States in which the implementation of ALEKS at the college/ university level has increased mathematical knowledge and reduced the number of remedial math courses needed. One case study out of Utah Valley University noted that many of their students take two years off for religious studies. These students, upon returning, often found themselves needing to take remedial math courses as they had not been exposed to many of the mathematical concepts being assessed in the placement test for a few years. Utah Valley University implemented a 1 credit hour course known as Math100R where students work in an ALEKS preparation course, the course concludes with their math placement exam. As a result, Utah Valley University, noted that many students have eliminated at least one four

to five credit hour mathematical course they are required to take, resulting in the students saving money and time towards their degree. ("Research and Case Studies")

Studies independent of McGraw-Hill, the administrators of ALEKS, have also been conducted. Judy Taylor conducted a study involving students who were enrolled in a remedial math course at two different colleges. (Taylor, 2008) The study was voluntary and only 54 ALEKS participants and 39 traditional lecture style participants, out of the total 1500 invited participants, agreed to participate. Students were given a pre and post-test of forty eight algebraic multiple choice questions, along with a pre and post-test questionnaire on mathematical anxiety. The results showed that both students in the traditional lecture classroom and the ALEKS classroom had improvements in their algebra skills, with the traditional classroom scoring slightly higher than the ALEKS classroom, but not statistically significant. The most interesting results of the study came from the questionnaire on anxiety, the ALEKS group showed reduced anxiety after the remedial course through ALEKS, whereas the traditional lecture style classroom showed a statically significant increase in mathematically anxiety. (Taylor, 2008) While the results are interesting, conclusions from the study are hard to make as the sample size was extremely small. Students were required to register on a website if they wanted to be included in the study, and then only those students that registered were given the algebraic pre and post-test, along with the pre and post-post math anxiety questionnaire. Follow up was not conducted with the students who did not reply, had follow up occurred they may have been able to increase the participants in the study, or at least gained a better understanding as to why students did not want to participate. In addition, closer collaboration with the colleges could have resulted in incorporating the study within the

class, so that participants were not required to take additional test outside of the course of study.

Similar to Taylor's study, a study on engagement theory, which suggests that when students are engaged in their learning they find more success and value in the process, thus less anxiety, was examined. (Kearsley & Shneiderman, 1998) The study was conducted at The University of Toledo in 2014 the adaptive learning software ALEKS was examined for effectiveness of the engagement theory in a credit bearing course, college algebra. (Stuve, 2015) Students enrolled in the college algebra class were either enrolled in a course taught in a traditional lecture style classroom, 426 students, or were enrolled in a class taught solely through the ALEKS adaptive learning software, 728 students. The results of student success on the final exam were analyzed through an independent t-test and showed students in the ALEKS course performed statistically higher than those students in the lecture style course. In addition, students were given a survey to analyze whether or not they enjoyed the material they were learning, whether they felt the material was useful, and if they felt they had to study more for the college algebra course compared to the other courses they were enrolled in. In all questions contained in the survey no statistical significance emerged between students who were enrolled in the traditional lecture classroom and students who were enrolled in the ALEKS classroom. While the study found, the students scored higher with the ALEKS course, it did not find, through the survey, that students felt more engaged and connected to course work. (Stuve, 2015) The results on the final exam were promising as students enrolled in the ALEKS course were gaining and retaining the material from the college algebra course. The analysis on student engagement was conducted at the end of the

course, when students are fatigued and exhausted from the course and ready to move on to a new semester with new courses, thus the effectiveness of the engagement may have been skewed and may have been more effectively assessed throughout the course and not just at the end of the course.

Middle and High Schools Utilizing ALEKS

ALEKS is also being implemented in elementary, middle, and high school math classes across the country, with ALEKS offering over thirty different mathematical products aligned with common core standards. (aleks.com) Achieve High School in rural South Carolina recently studied whether utilizing ALEKS in their one of their geometry class rooms, over a six-week period, would increase the student's geometric knowledge and understanding as compared with the students who did not utilize ALEKS. A survey was also utilized to assess the students attitude towards math at the beginning and end of the six-week period. (Oueini, 2019) During the six-week period two unit test were administered, and in both cases the experimental group with ALEKS scored higher than the control group that only received teacher led direct instruction, however the differences were not statistically significant for either unit test. When examining the student's attitudes towards mathematics and their belief on their ability to learn and understand the content, the students in the experimental group utilizing ALEKS showed statistically significant increases in their ability to understand and be successful as compared with the students in the control group. (Oueini, 2019) Oueini notes in the study that students at Achieve High School have struggled with end of course, state standardized test, with only 43% of them passing the Algebra I end of course exam,

however the study was implemented within geometry classrooms and only utilized with teacher based assessments over a six week period, so it is unclear whether ALEKS would benefit students with long term retention of the material as assessed in an end of course exam. The study also only contained a short six week period, where ALEKS may have still seemed new and exciting to the students. It is unclear whether the students would have maintained their increased belief in their ability to understand and succeed if ALEKS were implemented for the entire year, and not just a six week trial.

The mathematical achievement gap between African American and Caucasian students is prevalent throughout all education levels, not just in college. The Civil Rights Act of 1964 outlawed discrimination and called for equal educational opportunities regardless of race, yet over fifty years later and the achievement gap is still very distinct. ("Racial and Ethnic Achievement Gaps") An afterschool tutoring program contained within five middle schools in Tennessee assessed the effects of ALEKS to close the gap between the achievement of 128 sixth grade students, 107 which were African American and 21 which we Caucasian. The students were randomly assigned to two groups, the experimental group which would use ALEKS throughout the year long after school program, and the control group which would use teacher led direct instruction and practice problems throughout the year long after school program. The study analyzed the student's 5th grade state standardized test scores, where a clear achievement gap was noted, with their 6th grade state standardized test scores. When all 128 students in the after-school program were included, the 6th grade scores showed the Caucasian students scored higher than the African American students, however the difference was no longer statistically significant. When comparing just the students who utilized ALEKS, the

results showed an even smaller achievement gap as compared to the control group, however the difference between the two groups was not statistically significant. (Cheney, 2011) From the study, it is clear additional after school tutoring, whether through teacher or an adaptive learning software, can help lower the achievement gap, an important issue that needs to be addressed throughout the country.

Summary

The purpose of this chapter is to examine retention studies, the effects of remedial math on students, and the ability for ALEKS to help with retention in both college mathematical courses and middle/high school mathematical courses.

Retention studies have shown that students perform better in the classroom when practice is completed through spaced repetition and the types and styles of the problems are varied. The benefits of the repetition studies are promising in the classroom however; the last decade has shown nearly unchanged results on mathematical state standardized testing with only thirty-four percent of eighth grade students performed proficient or above in 2019. (Richards, 2019)

A deficit in mathematical ability is leading to many students being placed in remedial math courses as they enter college, with a high proportion of those students being African American. The effects of remedial courses have shown to be detrimental to a student's ability to graduate college and as a result colleges and universities are looking for ways to help students gain the mathematical knowledge needed to be successful in college, without being stuck in a never-ending cycle of costly remedial courses. (Hanford, 2016)

ALEKS, an adaptive learning software, has shown promising success with helping college students gain the necessary mathematical skills to be successful in college credit bearing courses, without spending large amounts of time and money in remedial courses. In addition, ALEKS has shown promising results in the middle school and high school setting with helping students increase their mathematical retention and lessen the achievement gap between African American and Caucasian students. Additional long term studies are needed to examine whether ALEKS is effective in decreasing the achievement gap on standardized testing, and whether ALEKS is able to help all students collectively retain their mathematical knowledge longer in order to increase achievement levels on standardized testing.

CHAPTER III: METHODOLOGY

This chapter will examine the setting and participants of the study, the instruments utilized, the procedure for collecting the data and the analysis that will be used to answer the research questions.

The purpose of this study is to examine the effects of a three tier ALEKS program on the retention of mathematical knowledge as assessed on the student's ACT math score. Students who did not utilize the three tier ALEKS program prior to taking the statewide ACT their junior year were compared with students who did utilize the three tier ALEKS program prior to the statewide ACT their junior year. Students' AIR scores for algebra and geometry, which were both administered prior to the implementation of the three tier ALEKS program, are being analyzed as a covariate to ensure one group of students did not have a strong mathematical understanding. Minutes spent in ALEKS will also be analyzed to determine if it can predict ACT scores.

Setting and Participants

Pickerington, Ohio is a suburb of Columbus, Ohio located fifteen miles from downtown Columbus. Eighty two percent of the residents own their house, with the other eighteen percent of the residents renting either a stand-alone house or an apartment. The median house price in Pickerington is $209, 225. ("About Our Community") Within the city limits of Pickerington is Pickerington Local Schools. The district is the 15th largest district in the State of Ohio with over 10,600 students. According to the latest State of Ohio school report card, released in September 2019, the district contains 57% white

non-Hispanic students, 25.5% black, 7.7% multiracial, 5.4% Hispanic, and 4.4% other. Within the district 28.2% of the students are economically disadvantaged, as they qualify for the USDA National School Lunch Program. ("School Report Card")

Pickerington Local Schools is divided into two pathways with one path leading to Pickerington High School Central and the other pathway leading to Pickerington High School North. The juniors and seniors included in the study are all students of Pickerington High School North. The demographics, according to the latest State of Ohio school report card, specifically for Pickerington High School North are 61.5% white, 22.1% black, 6% multiracial, 5.9% Hispanic, and 4.5% other with 25% of their population being economically disadvantaged. ("School Report Card") As evident by comparison of the demographics, Pickerington High School North is representative of the district as a whole.

The study will include juniors and seniors at Pickerington High School North. There are roughly 445 seniors and 425 juniors currently attending Pickerington High School North, all juniors and seniors that were not enrolled in AP Calculus, AP Statistics, or a College Credit Plus Math course their junior year at Pickerington High School North will be included in the study. Students who were enrolled in an AP math course and/or a CCP math course their junior year were not enrolled in ALEKS and thus they will not be included in the study. It is anticipated that roughly half of the students will qualify for the study, giving roughly 200 - 225 students per grade level. Analyzing a medium effect size with an alpha level of .05 and a power of .8 requires a sample size of approximately 158 students, well below the projected 400 - 450 total students in the study.

Instrumentation

American Institute for Research, AIR, was founded in 1946 as a non-profit organization creating aptitude and placement tests. Throughout the years AIR has played a pivotal role in the collection and analyzation of data for key educational legislation such as No Child Left Behind and Title I funding as part of the Elementary and Secondary Education Act. (air.org) AIR has also emerged as a leading provider of state assessments, with over 38% of all students enrolled in public education taking a state AIR assessment last year. The Ohio Department of Education, which has utilized end of course AIR assessments for numerous years, and reports an AIR score reliability rating of 80% and 76% for algebra and geometry respectively. ("Ohio's State Tests")

The ACT also has a long-standing history of assessing a student's knowledge. The ACT began in the late 1940s as many soldiers were returning from war without a high school diploma, Everett Lindquist, a professor of education and later a co-founder of the ACT, noticed a need and developed a high school equivalence test, allowing returning soldiers to earn, what we would refer to today as a GED and enter college. In the fall of 1959 the first ever ACT was given to 75, 406 high school students; the popularity of the ACT as a college admissions test continued to increase and by 1968 one million high school students took the ACT. Today the ACT is just as prevalent with college admissions, of the graduating class of 2019, 1.8 million students took the ACT which encompasses 52% of all 2019 high school graduates in the United States. (act.org)

The ACT holds a reliability rating of 92% within the math portion of the ACT, creating a reliable benchmark for colleges to use as an assessment of a student's mathematical knowledge. Currently ACT has set the college benchmark for math at a 22,

students who score at or above a 22 on the math portion of the ACT are deemed ready and capable of learning college level math. Across the United States the percentage of students who are scoring at or above a 22 is decreasing, with an all-time low of 39% for the graduating class of 2019. (act.org) Clearly, there is a disconnect between what students are retaining mathematically and what is needed to be successful in college math. Numerous curriculum companies have developed programs to help fill in gaps in a student's mathematical knowledge in an effort to raise their readiness for higher level math. ALEKS is an adaptive learning software, owned by McGraw Hill, that utilizes a unique artificial intelligence to initially and continually assess students. ALEKS is designed using Knowledge Space Theory, where a student is able to be assessed over hundreds of standards in a relatively short 25 – 30 question assessment. Utilizing the standards and how they are associated, the artificial intelligence software is able to determine what a student knows, what a student is ready to learn, what a student is not ready to learn as they do not have the prerequisite skills. ALEKS claims its artificial intelligence is able to correctly predict what a student is ready to learn with 90% accuracy, creating an effective way to individually hone in on specific standards a student needs to learn in order to be successful. (aleks.com)

Procedure

The study will include all juniors at Pickerington High School North that are currently enrolled in Algebra II, Pre-calculus, or Statistics as they are also enrolled in the three tier ALEKS course. The current seniors at Pickerington High School North that were enrolled in Algebra II, Pre-calculus, or Statistics during their junior year will also be

included in the study as the baseline. The students that are, or were enrolled in a CCP math course or an AP math course during their junior year will be excluded from the study as they are not currently enrolled in ALEKS. Permission has been received, and attached in the appendix, from Pickerington High School North principal, Mark Ulbrich, to conduct this study. Pickerington High School North currently has possession of the data as it is part of school records, and thus the data will be collected from the school administration after cleansing. The school administration will filter out any students that are or were enrolled in CCP math or AP math course during their junior year along with any students who were not enrolled in Pickerington City Schools for the three consecutive years of testing being examined, freshman (AIR algebra), sophomore (AIR geometry), and junior year (math ACT), and will cleanse the data from all student identifiers such as name and student ID number eliminating any chances for participants and their individual scores to be identified. All information received from Pickerington High School North administration for use of the study will remain confidential and the data will not be available during or after the study.

The data will be received in two excel documents, one for graduating class of 2020 (current seniors) and one for the graduating class of 2021 (current juniors), with a column listing their AIR algebra score, AIR geometry score, their math ACT score, gender, race, and for the graduating class of 2021 the number of hours they spent in ALEKS. IRB approval to conduct this study was received from Dr. Hamilton, chair of the IRB committee at Shawnee State on December 16th, 2019.

Data Processing and Analysis

The data is the study will be analyzed using the statistical software R. Descriptive statistics will be run across both groups, the 2020 graduating class that did not use ALEKS and the 2021 graduating class that did use ALEKS, on AIR Algebra scores, AIR Geometry score, and ACT scores.

An ANCOVA will be run to analyze the first research question.

> *1. Will statistically significant differences emerge in mean math ACT sub scores for students at Pickerington High School North who did not use ALEKS to prepare for the math portion of the ACT when compared with students who did use ALEKS to prepare for the math portion of the ACT when controlling for results from the AIR math test?*

In order to ensure the assumptions are met for an ANCOVA the Levene test will run to ensure the homogeneity of variances and the Shapiro Wilks test will be run to ensure normality. An ANOVA will be run over the covariates, AIR Algebra and AIR Geometry scores, to ensure there is no statistical significance thus implying independence of the covariates and an ANOVA will be run over the interaction of the variables to ensure there is no statistical significance thus implying homogeneity of regression slopes. In addition, a regression analysis will be run with predictors, AIR Algebra score, AIR geometry score, along with dichotomous variables ALEKS usage and response variable ACT score.

The second research question will be examined through a correlation analysis.

2. Will minutes spent on ALEKS correlate significantly with the math ACT sub score?

The graduating students of 2020, those that did not use ALEKS, being removed from the data, and a correlation analysis will be conducted to determine the correlation between the number of minutes spent in ALEKS and ACT math score. In addition, a regression model will be credited to examine if ACT scores can be predicted from minutes spent in ALEKS.

The methods described above to answer the research questions are in line with the methods utilized in similar studies. Tatjana Hrubik-Vulanovic conducted a study to determine if students in an ALEKS remedial course would perform as well as peers who did not need remedial math and/or students who did not need a remedial course in subsequent credit bearing math courses. An ANCOVA analysis was utilized to determine if there was any statistical significance on final exam scores between the groups with their math placement score being used as a covariate. (Hrubik-Vulanovic, 2013) In a different study conducted by Kristen Ann Pennington the effects of utilizing ALEKS as homework/practice problems on final exams was conducted using an ANCOVA analysis. Student's pretest scores were used as a covariate to examine if there was statistical significance on final exam scores with the use of ALEKS. (Pennington, 2013)

Summary

The purpose of this chapter is to describe the setting and participants, explain the instrumentation utilized in the study, describe the procedure for the collection of the data and the methods that will be used to analyze the research questions.

With permission of the administration at Pickerington High School North, ACT math results for the graduating class of 2020 and 2021 will be examined to determine if

the usage of a three tier ALEKS program with the graduating class of 2021 has improved mathematical retention and resulted in an increase of the schools mean ACT math score. The student's AIR Algebra and AIR Geometry scores, both of which were administered prior to the implementation of the three tier ALEKS program, will be utilized as a covariate to ensure one graduating class did not have a stronger mathematical understanding. An analysis will also be conducted to see if the number of minutes spent in ALEKS can predict a student's ACT score. Data will be cleansed prior to being received from the administration of Pickerington High School North to ensure all identifying information is removed from the data maintaining the confidentiality of all participants and their math scores.

CHAPTER IV: RESULTS

This chapter will describe the participants of the study, how data was received, and an analysis of the data. The purpose of this study is to examine whether ALEKS, (Assessment and Learning in Knowledge Spaces) is as effective in the high school setting as it has been shown in the college setting by analyzing whether ALEKS is able to help bridge the gap on retention of previously learned material as assessed on the math portion of the ACT. The research questions asked were:

1. Will statistically significant differences emerge in mean math ACT sub scores for students at Pickerington High School North who did not use ALEKS to prepare for the math portion of the ACT when compared with students who did use ALEKS to prepare for the math portion of the ACT when controlling for results from the AIR math test?
2. Will hours spent on ALEKS correlate significantly with the math ACT sub score?

Participants

The study included juniors and seniors at Pickerington High School North. There are N = 445 (51.1%) seniors and N = 425 (48.9%) juniors currently attending Pickerington High School North. Students who did not take a math class their junior year, or were enrolled in AP Calculus, AP Statistics, or a College Credit Plus Math course their junior year at Pickerington High School North were removed from the study resulting in a sample size of N = 260 (54.7%) seniors (control group) and N = 215 (45.3%) juniors (experimental group) included in the study.

Data Cleansing

The data was received from Pickerington High School North administration and was cleansed prior to receiving the data. Two spreadsheets were received, one for the control group (current seniors) and one for the experimental group (current juniors). Each spreadsheet contained a column for the students AIR algebra score, AIR geometry score, ACT math score, gender, race, junior level math course, and teacher for that course. The spreadsheet for the juniors also contained a column for the number of minutes spent in ALEKS. Neither spreadsheet contained any student names or identification numbers.

Descriptive Statistics

The seniors had a mean Algebra AIR score (standard deviation) of 3.03 (1.00) with a mean Geometry score of 2.80 (1.13) and a mean ACT math sub score of 19.87 (4.62). Table 1 presents the mean and standard deviation for the seniors by gender, Table 2 presents the mean and standard deviation for the seniors by race, and Table 3 presents the mean and standard deviation for the seniors by course.

When examining the Algebra AIR scores, Geometry AIR scores, and Math ACT scores, statistical significance did not appear between the genders, $t(258) = .77$, $p = .44$, $t(258) = .31$, $p = .76$, and $t(258) = -.28$, $p = .78$; respectively, therefore differences in Algebra AIR, Geometry AIR, and Math ACT scores were not significant across gender.

Table 1

Mean (Standard Deviation) for Seniors by Gender

	Algebra AIR	Geometry AIR	Math ACT
Female (n=139)	3.08 (0.99)	2.82 (1.12)	19.80 (4.63)
Male (n=121)	2.98 (1.01)	2.78 (1.14)	19.96 (4.62)
	t(258) = 0.77 p = .44	t(258) = 0.31 p = .76	t(258) = -0.28 p = .78

When examining the Algebra AIR scores, Geometry AIR scores, and the Math ACT scores, statistical significance did appear between Race, $F(4, 255) = 6.592$, $p < .001$, $F(4, 255)$, $p < .001$, and $F(4, 255) = 7.588$, $p < .001$, respectively. A Bonferroni post hoc test revealed statistical significance in the Algebra AIR scores between white and black, $p < .001$ with a moderate effect size $g = .71$. Likewise, a Bonferroni post hoc test also revealed statistical significance in the Geometry AIR score and the Math ACT score between black and white, $p < .001$ with a large effect size $g = .83$, and $p < .001$, respectively. There is a significant mathematical achievement difference on AIR and ACT assessments between white and black students at Pickerington High School North. No other race comparisons were statistically significant.

Table 2

Mean (Standard Deviation) for Seniors by Race

	Algebra AIR	Geometry AIR	Math ACT
White (n=170)	3.25 (0.95)	3.05 (1.06)	20.86 (4.42)
Black (n=54)	2.57 (0.98)	2.17 (1.11)	17.31 (4.30)
Multiracial (n=18)	2.83 (0.92)	2.67 (0.97)	20.11 (4.61)
Hispanic (n=13)	2.54 (1.05)	2.31 (1.18)	17.69 (4.09)
Asian (n=5)	2.60 (1.14)	2.80 (1.30)	18.80 (4.55)
	$F(4, 255) = 6.592$, $p < .001$	$F(4, 255) = 7.819$, $p < .001$	$F(4, 255) = 7.588$, $p < .001$

When examining the Algebra AIR scores, Geometry AIR scores, and the Math ACT scores, statistical significance did appear between the different Courses, $F(4, 255) = 19.70$, $p < .001$, $F(4, 255) = 23.61$, $p < .001$, and $F(4, 255) = 37.67$, $p < .001$, respectively. A Bonferroni post hoc test revealed statistical significance in the Algebra AIR scores between students enrolled in Algebra II and Honors Algebra II, $p < .001$ with a large effect size $g = .86$, between Algebra II and Honors PreCalculus, $p < .001$ with a large effect size $g = 1.19$, and between Algebra II and PreCalculus, $p < .01$, with a moderate effect size $g = .76$. A Bonferroni post hoc test also revealed statistical significance in the Geometry AIR scores between students enrolled in Algebra II and Honor Algebra II, $p < .001$ with a large effect size $g = .82$, and between Algebra II and Honors PreCalculus, $p < .001$, with a large effect size $g = 1.42$. Bonferroni post hoc test revealed statistical significance in the Math ACT scores between students enrolled in Algebra II and Honors Algebra II, $p < .001$, with a large effect size $g = 1.42$, between students enrolled in Algebra II and Honors PreCalculus, $p < .001$, with a large effect size

g = 1.87, between Algebra II and PreCalculus, $p < .001$, with a large effect size, g = 1.05, and between Honors Algebra II and Honors PreCalculus, $p < .001$, with a large effect size g = 1.32. There is a significant mathematical achievement difference on AIR and ACT assessments between students enrolled in Algebra II and the other courses. Students not accelerated in math are enrolled in Algebra II their junior year, whereas students accelerated in math are enrolled in either Honors Algebra II, PreCalculus, Honors Precalculus, or Statistics so it is not surprising that their scores are significantly higher than those students enrolled in Algebra II.

Table 3

Mean (Standard Deviation) for Seniors by Course

	Algebra AIR	Geometry AIR	Math ACT
Algebra II (n=130)	2.56 (1.04)	2.27 (1.11)	17.45 (3.96)
Honors Algebra II (n=52)	3.38 (0.66)	3.12 (0.78)	20.21 (3.22)
PreCalculus (n=21)	3.33 (0.80)	2.86 (0.91)	21.57 (3.57)
Honors PreCalculus (n=53)	3.70 (0.67)	3.74 (0.79)	24.64 (3.45)
Statistics (n=4)	3.50 (0.58)	3.25 (0.50)	22.00 (4.00)
	$F(4, 255) = 19.70$, $p < .001$	$F(4, 255) = 23.61$, $p < .001$	$F(4, 255) = 37.67$, $p < .001$

The juniors had a mean Algebra AIR score (standard deviation) of 3.00 (0.96) with a mean Geometry score of 2.83 (1.06) and a mean ACT math sub score of 21.64 (4.34). The juniors were the experimental group that worked through the three course ALEKS progression and spent a mean time in ALEKS of 1947.65 minutes (629.68). Table 4 presents the mean and standard deviation for the juniors by gender, Table 5

presents the mean and standard deviation for the juniors by race, Table 6 presents the mean and standard deviation for the juniors by course, and Table 7 presents the mean and standard deviation for the juniors by teacher.

When examining the Algebra AIR scores, Geometry AIR scores, Math ACT scores, and the minutes a student spent in ALEKS, statistical significance did not appear between the genders, $t(213) = .667$, $p = .43$, $t(213) = .931$, $p = .35$, $t(213) = .078$, $p = .94$, and $t(213) = 1.875$, $p = .06$, respectively, therefore gender was not a significant factor in how the juniors performed on the AIR test or the Math ACT.

Table 4

Mean (Standard Deviation) for Juniors by Gender

	Algebra AIR	Geometry AIR	Math ACT	Time in ALEKS minutes
Female (n=106)	3.17 (0.92)	2.90 (1.05)	21.67 (3.99)	2028.82 (614.34)
Male (n=109)	2.83 (0.97)	2.76 (1.07)	21.61 (4.67)	1868.71 (637. 15)
	$t(213) = .667$, $p = .43$	$t(213) = .931$, $p = .35$	$t(213) = .078$, $p = .94$	$t(213) = 1.875$, $p = .06$

When examining the Algebra AIR scores, Geometry AIR scores, the Math ACT scores, and the minutes a student spent in ALEKS, statistical significance did appear between the different Race for the Geometry AIR scores and the Math ACT scores, $F(4, 210) = 4.19$, $p < .05$, and $F(4, 210)$, $p < .05$, respectively. A Bonferroni post hoc test revealed statistical significance in the Geometry AIR scores between white and black, $p < .05$ with a moderate effect size $g = .56$ and between white and Hispanic, $p < .005$, with a large effect size $g = .93$. Likewise, a Bonferroni post hoc test also revealed

statistical significance in the Math ACT score between black and white, $p < .05$ with a week to moderate effect size $g = .46$. There is a mathematical achievement difference on the Geometry AIR assessment between white and black and between white and Hispanic students at Pickerington High School North. In addition, there is also a notable achievement difference, although smaller, on the Math ACT between white and black students at Pickerington High School North. No other race comparisons were statistically significant.

Table 5

Mean (Standard Deviation) for Juniors by Race

	Algebra AIR	Geometry AIR	Math ACT	Time in ALEKS minutes
White (n=133)	3.12 (0.86)	3.00 (0.98)	22.24 (4.45)	1927.95 (660.91)
Black (n=43)	2.65 (1.04)	2.44 (1.03)	20.26 (3.79)	1959.95 (557.81)
Multiracial (n=15)	3.00 (1.00)	2.80 (1.08)	20.60 (3.64)	1904.87 (578.62)
Hispanic (n=12)	2.92 (1.00)	2.08 (1.00)	18.08 (3.18)	1833.00 (473.05)
Asian (n=12)	2.92 (1.38)	3.08 (1.51)	22.58 (5.26)	2290.00 (695.76)
	$F(4, 210) = 2.03$, $p = .09$	$F(4, 210) = 4.19$, $p < .05$	$F(4, 210) = 3.03$, $p < .05$	$F(4, 210) = 1.04$, $p = .39$

When examining the Algebra AIR scores, Geometry AIR scores, Math ACT scores, and the minutes spent in ALEKS, statistical significance did appear between the different Courses, $F(4, 210) = 22.63$, $p < .001$, $F(4, 210) = 25.31$, $p < .001$, $F(4, 210) = 53.83$, $p < .001$, and $F(4, 210) = 15.65$, $p < .001$, respectively. A Bonferroni post hoc test

revealed statistical significance in the Algebra AIR scores between students enrolled in Algebra II and Honors Algebra II, $p < .001$ with a large effect size $g = 1.37$, between Algebra II and Honors PreCalculus, $p < .001$ with a large effect size $g = 1.26$, between Algebra II and PreCalculus, $p < .01$, with a large effect size $g = 1.01$, and between Algebra II and Statistics, $p < .01$, with a large effect size $g = .88$. A Bonferroni post hoc test also revealed statistical significance in the Geometry AIR scores between students enrolled in Algebra II and Honor Algebra II, $p < .001$ with a large effect size $g = 1.33$, between Algebra II and Honors PreCalculus, $p < .001$, with a large effect size $g = 1.65$, and between Algebra II and Statistics, $p < .001$, with a large effect size $g = .98$. Bonferroni post hoc test revealed statistical significance in the Math ACT scores between students enrolled in Algebra II and Honors Algebra II, $p < .001$, with a large effect size $g = 1.49$, between students enrolled in Algebra II and Honors PreCalculus, $p < .001$, with a large effect size $g = 2.96$, between Algebra II and PreCalculus, $p < .001$, with a large effect size, $g = 1.74$, between Algebra II and Statistics, $p < .001$, with a large effect size $g = 1.66$, between Honors Algebra II and Honors PreCalculus, $p < .001$, with a large effect size $g = 1.51$, and between Honors PreCalculus and Statistics, $p < .01$, with a moderate effect size $g = .78$. Bonferroni post hoc test revealed statistical significance in the minutes a student spent in ALEKS between students enrolled in Algebra II and Honors Algebra II, $p < .01$, with a moderate effect size $g = .59$, between Algebra II and Honors PreCalculus, $p < .001$, with a large effect size $g = 1.87$, between Honors Algebra II and Honors PreCalculus, $p < .001$, with a large effect size $g = 1.23$, and between Honors PreCalculus and Statistics, $p < .001$, with a large effect size $g = 1.53$. Students not accelerated in math are enrolled in Algebra II their junior year, whereas students

accelerated in math are enrolled in either Honors Algebra II, PreCalculus, Honors Precalculus, or Statistics so it is not surprising that their AIR and ACT scores are significantly higher than those students enrolled in Algebra II. All students were given a goal of 60 minutes per week in ALEKS, so it is surprising that there is statistical significance in the minutes a student spent in ALEKS and the different courses as all students should have been working in ALEKS an equal amount of time regardless of course.

Table 6

Mean (Standard Deviation) for Juniors by Course

	Algebra AIR	Geometry AIR	Math ACT	Time in ALEKS minutes
Algebra II (n=115)	2.51 (0.92)	2.29 (0.95)	18.98 (3.06)	1763.60 (541.01)
Honors Algebra II (n=46)	3.65 (0.53)	3.50 (0.78)	23.52 (2.99)	2088.54 (566.06)
PreCalculus (n=14)	3.43 (0.75)	3.07 (0.92)	22.21 (2.83)	1947.21 (483.57)
Honors PreCalculus (n=21)	3.62 (0.59)	3.81 (0.68)	27.05 (2.71)	2773.14 (518.24)
Statistics (n=19)	3.32 (0.89)	3.21 (0.79)	24.32 (3.93)	1808.42 (713.58)
	$F(4, 210) = 22.63$, $p < .001$	$F(4, 210) = 25.31$, $p < .001$	$F(4, 210) = 53.83$, $p < .001$	$F(4, 210) = 15.65$, $p < .001$

When examining the Algebra AIR scores, Geometry AIR scores, Math ACT scores, and the minutes spent in ALEKS, statistical significance did appear between the different Teachers, $F(7, 207) = 5.00$, $p < .001$, $F(7, 207) = 5.86$, $p < .001$, $F(7, 207) = 22.50$, $p < .001$, and $F(7, 207) = 13.03$, $p < .001$, respectively. A Bonferroni post hoc test revealed statistical significance in the Algebra AIR score between Teacher

D and Teacher B, $p < .05$, with a moderate effect size $g = .66$, between Teacher D and Teacher E, $p < .01$, with a large effect size $g = .87$, and between Teacher E and Teacher G, $p < .05$, with a moderate to large effect size $g = .8$. A Bonferroni post hoc test also revealed statistical significance in the Geometry AIR scores between Teacher D and Teacher E, $p < .001$, with a large effect size $g = 1.24$, and between Teacher D and Teacher F, $p < .001$, with a large effect size $g = 1.57$. Bonferroni post hoc test revealed statistical significance in the Math ACT scores between Teacher D and Teacher B, $p < .001$, with a large effect size $g = 2.36$, between Teacher D and Teacher C, $p < .001$, with a large effect size $g = 1.37$, between Teacher D and Teacher E, $p < .001$, with a large effect size $g = 2.38$, and between Teacher D and Teacher F, $p < .001$, with a large effect size $g = 3.07$. Bonferroni post hoc test revealed statistical significance in the minutes a student spent in ALEKS between Teacher A and Teacher D, $p < .001$, with a large effect size $g = 1.69$, between Teacher B and Teacher D, $p < .001$, with a large effect size $g = 1.34$, between Teacher D and Teacher E, $p < .001$, with a large effect size $g = 2.13$, and between Teacher D and Teacher F $p < .001$, with a large effect size $g = 2.09$. Teacher D taught Honors PreCalculus, those students are accelerated in their mathematical skills, as a result it is not surprising that their scores on the AIR assessments and the ACT are significantly higher than that of the other Teachers. All students were given a goal of 60 minutes per week in ALEKS, Teacher D's students spent an average of 2763.23 minutes in ALEKS over the course of the 25 week period which equates to an average of 110.57 minutes per week, nearly double the students goal. The increased time Teacher D's students spent in ALEKS created a statistically significant difference between the time spent in ALEKS for the other Teachers.

Table 7

Mean (Standard Deviation) for Juniors by Teacher

	Algebra AIR	Geometry AIR	Math ACT	Time in ALEKS minutes
Teacher A (n=15)	3.20 (0.86)	3.20 (0.86)	24.27 (4.57)	1706.87 (743.54)
Teacher B (n=55)	2.84 (0.90)	2.67 (0.98)	20.42 (3.36)	2056.49 (526.45)
Teacher C (n=12)	3.42 (0.79)	3.00 (0.95)	24.08 (3.03)	1949.33 (496.11)
Teacher D (n=22)	3.64 (0.58)	3.82 (0.66)	28.00 (2.65)	2764.23 (507.48)
Teacher E (n=67)	2.75 (1.12)	2.48 (1.17)	19.67 (3.70)	1665.15 (512.37)
Teacher F (n=26)	2.65 (0.69)	2.58 (0.86)	19.12 (3.01)	1661.58 (529.27)
Teacher G (n=12)	3.67 (0.49)	3.33 (0.89)	24.75 (1.71)	2369.75 (489.71)
Teacher H (n=6)	3.67 (0.82)	3.33 (0.52)	24.83 (1.33)	2104.33 (471.04)
	$F(7, 207) = 5.00$, $p < .001$	$F(7, 207) = 5.86$, $p < .001$	$F(7, 207) = 22.5$, $p < .001$	$F(7, 207) = 13.03$, $p < .001$

Hypothesis Testing

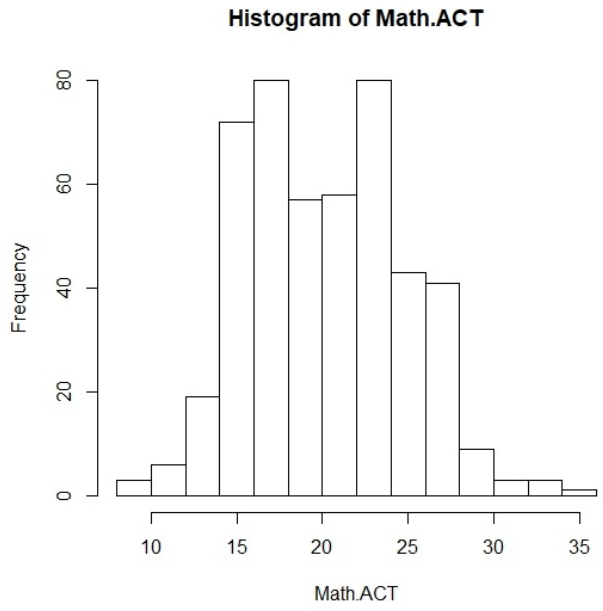
Question 1:

Will statistically significant differences emerge in mean math ACT sub scores for students at Pickerington High School North who did not use ALEKS to prepare for the math portion of the ACT when compared with students who did use ALEKS

to prepare for the math portion of the ACT when controlling for results from the AIR math test?

An ANCOVA was run to analyze the first research question with the assumptions verified prior to the completion of the ANCOVA. The data comes from two different graduating classes in which students can not overlap and thus independence is observed. The Shapiro Wilks test was run to check for normality with $W=0.98$, $p < .001$. Figure 1 below shows a histogram of the students ACT scores, which indicates skewness and a distribution that is multimodal.

Figure 1: Histogram of Math ACT scores



A Levene Test was run to check for homogeneity of variances with $F(1, 473) = 1.272$, $p = .26$ verifying that the equal variance assumption is met. In order to ensure there is independence of the covariates an ANOVA across the covariates was run $F(1, 473) = .004$, $p = .949$ showing no statistical significance and thus independence of the covariates. An ANOVA was also run over the interaction $F(1, 467) = .097$, $p = .756$

showing no statistical significance and thus equal regression slopes. An ANCOVA was run on math ACT scores across the use of ALEKS while controlling for the student's previous Algebra AIR score and Geometry AIR score, the ANCOVA revealed the use of ALEKS was statistically significant $F(1, 471) = 17.596$, $p < .001$.

When examining gender, both females and males showed an increase in their math ACT score with the use of ALEKS, however the male students had a greater statistical significance $t(226) = 19.013$, $p < .001$, as compared to the females $t(241) = 4.6521$, $p < .05$. Likewise, when examining race, all racial subgroups showed an increase in their mean math ACT score with the use of ALEKS; however, African American students showed the greatest statistical significance on their math ACT score when utilizing ALEKS $F(1, 93) = 15.013$, $p < .001$. Caucasian students also showed statistical significance with the use of ALEKS $F(1, 299) = 7.783$, $p < .01$. All other subgroups demonstrated an increase in mean score, but the differences were not statistically significant. It is important to note that the other three subgroups, Multiracial, Hispanic, and Asian, all had sample sizes below thirty, much smaller than the sample size of African American and Caucasian students, and as a result of the small sample sizes, even though there was an increase in the mean ACT scores, the results are not statistically significant for those groups.

A Tukey post hoc analysis revealed statistical significance in the Math ACT scores between students who used ALEKS and students who did not use ALEKS, there was no statistical significance between Algebra AIR scores or Geometry AIR scores and the use of ALEKS. Partial eta-square was calculated for each predictor to determine its effect size of the student's math ACT score. ALEKS has an effect size of .147 on a

student's math ACT score, whereas the student's algebra AIR score and the student's geometry AIR score have an effect size on a student's math ACT score of .129 and .278 respectively. While ALEKS has shown to be statistically significant in improving a student's math ACT score, it is prevalent by the effect size that a student's prior knowledge and understanding of mathematical concepts also weighs heavily in the student's score.

Linear Analysis

A linear model was created to predict a student's math ACT score from their Algebra AIR score, Geometry AIR score, and whether or not they utilized ALEKS (control versus experimental). The Algebra AIR score and the Geometry AIR scores were graphed over the residuals as illustrated in Figures 2 and 3 to ensure linearity. The fitted values were also graphed over the residuals to ensure homogeneity of variances. The residuals are relatively symmetrical with respect to the fitted values, with the exception of a couple of fitted values which had a residual value of nearly 10, Figure 4.

Figure 2: Algebra AIR scores graphed over the residuals

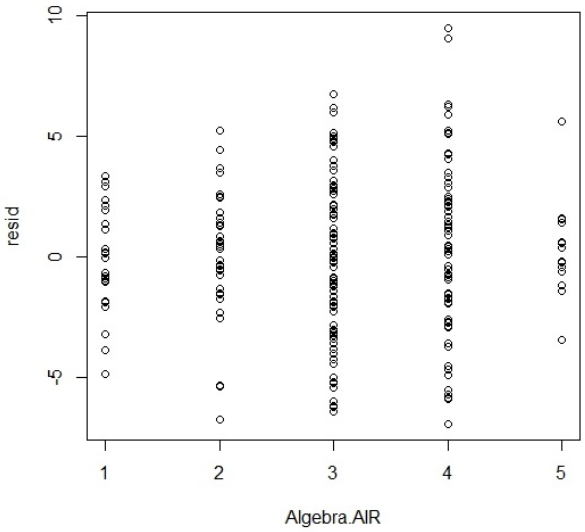


Figure 3: Geometry AIR scores graphed over the residuals

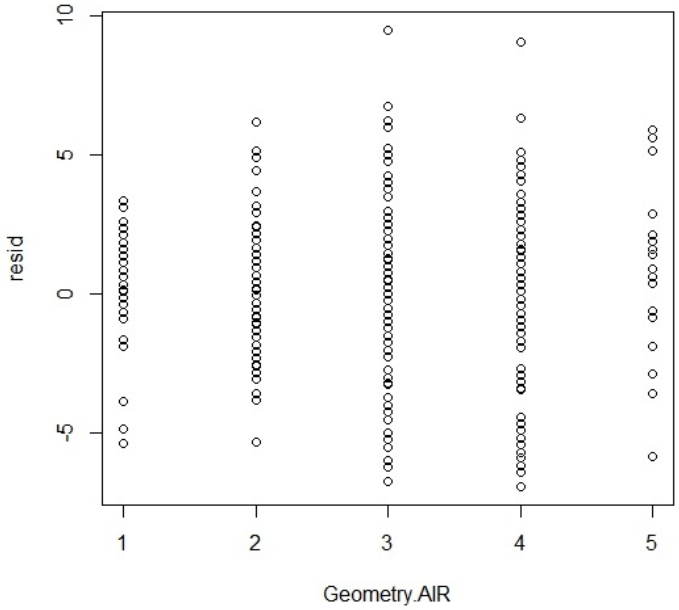
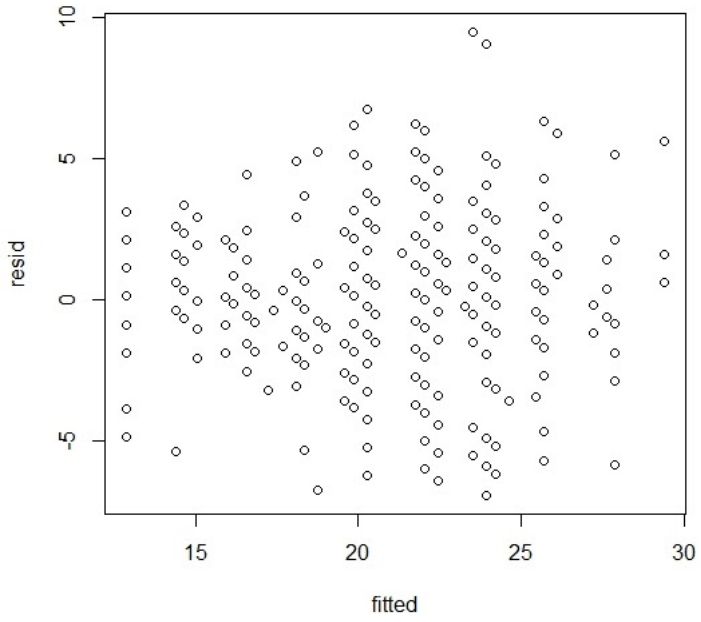


Figure 4: Fitted values plotted over Residuals



To ensure a normal population a histogram of the residuals was created. The histogram is relatively symmetrical with no major skewness, Figure 5. The QQ Plot shows only a few points deviating from the linear line, Figure 6.

Figure 5: Histogram of the Residuals

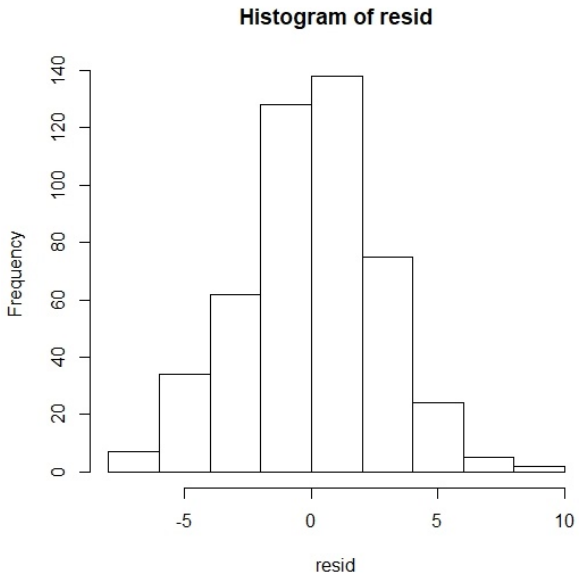
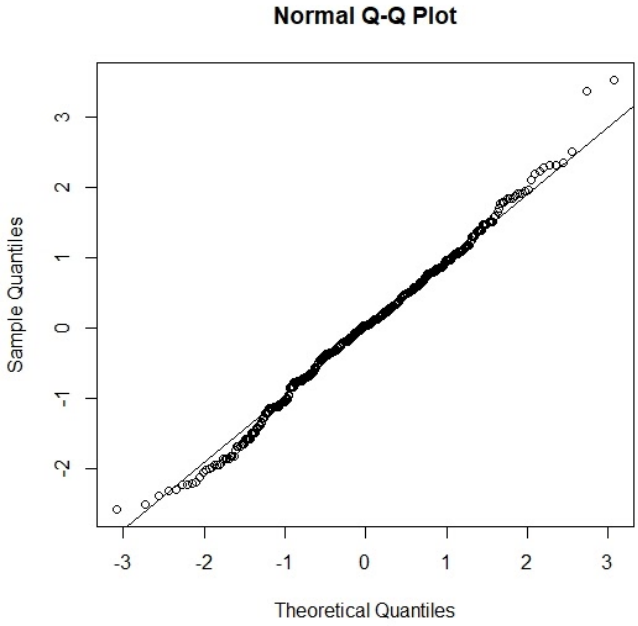


Figure 6: QQ Plot



The Durbin Watson test was run to ensure independence, with DW = 1.955, p = .294. The variance inflation factor was also run to ensure multicollinearity; the results are listed in Table 8.

Table 8 Variance Inflation Factors

	Algebra AIR	Geometry AIR	ALEKS
VIF	2.051	2.050	1.002

A regression model was conducted, Table 9, along with the corresponding confidence intervals for each variable, Table 10. The regression model reveals, while controlling for a student's Algebra AIR score and a student's Geometry AIR score, a student's Math ACT score increases 1.767 with the use of ALEKS.

Table 9

Multiple Regression Analysis

	Estimates	Standard Error	t value	p - value
Intercept	9.211	.422	21.839	$p < .001$
Algebra AIR	1.506	.180	8.349	$p < .001$
Geometry AIR	2.175	.162	13.456	$p < .001$
ALEKS	1.767	.249	7.104	$p < .001$
	$F(3, 471) = 298.1$, $p < .001$		Adjusted R^2 =.653	

Table 10

Confidence Intervals

	Lower	Upper
Intercept	8.38	10.04
Algebra AIR	1.15	1.86
Geometry AIR	1.86	2.49
ALEKS	1.28	2.26

Boxplots of the independent and dependent variables were constructed to examine the possibility of any outliers, Figures 7, 8, 9, and 10.

Figure 7: Boxplot of Algebra AIR scores

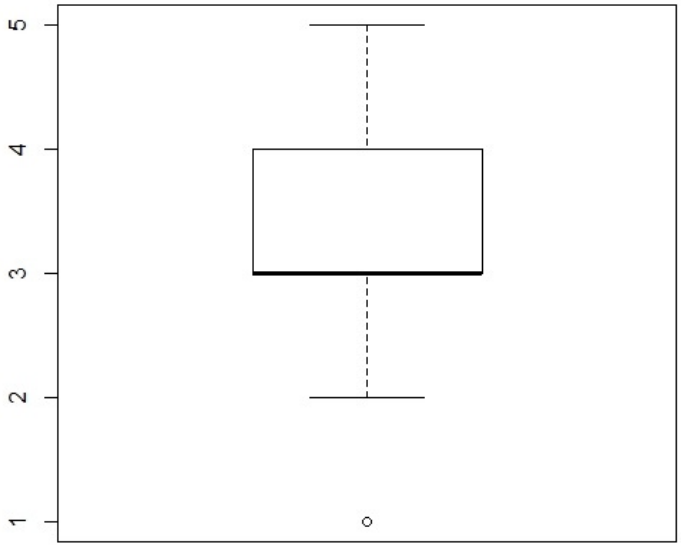


Figure 8: Boxplot of Geometry AIR scores

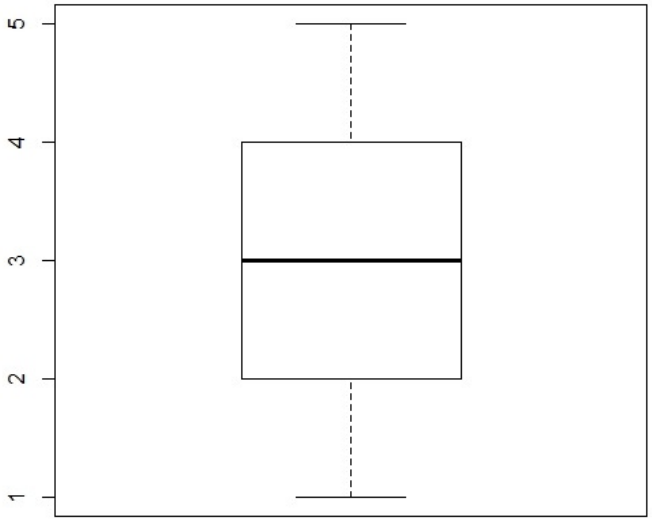
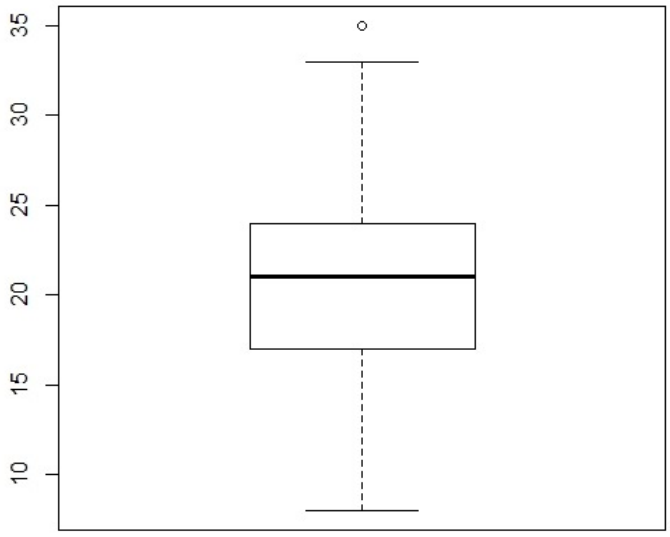


Figure 9: Boxplot of Math ACT scores



The boxplots revealed possible outliers in the data so the standard residuals were further examined. Case 36 and 406 were found to have standard residual values of 3.37 and 3.53 respectively. Both cases had an absolute value greater than three and were deemed outliers and removed from the data set. An additional regression model was run without the outliers, Table 11, and the corresponding confidence intervals, Table 12.

Table 11

Multiple Regression Analysis without Outliers

	Estimates	Standard Error	t value	p - value
Intercept	9.295	.412	22.550	$p < .001$
Algebra AIR	1.460	.178	8.272	$p < .001$
Geometry AIR	2.183	.158	13.814	$p < .001$
ALEKS	1.756	.243	7.213	$p < .001$
	$F(3, 469) = 306.4$, $p < .001$		Adjusted R^2 =.660	

Table 12

Confidence Intervals

	Lower	Upper
Intercept	8.49	10.11
Algebra AIR	1.11	1.81
Geometry AIR	1.87	2.49
ALEKS	1.28	2.23

The regression model without the outliers revealed a higher adjusted R^2, indicating model improvement. While controlling for a student's Algebra AIR score and a student's Geometry AIR score, a student's Math ACT score increases 1.756 with the use of ALEKS. While the use of ALEKS is shown to have an increase effect in a student's math ACT score, the regression analysis shows that a student's initial understanding of algebra and geometry as assessed on the AIR test, which has a score range of 1 to 5, plays a stronger role in determining the student's achievement on the math portion of the ACT.

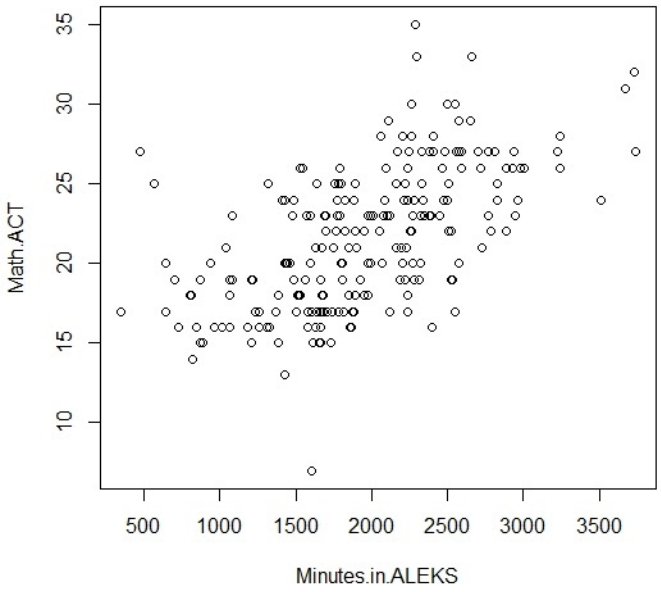
Question 2:

Will minutes spent on ALEKS correlate significantly with the math ACT sub score?

A correlation analysis was run on the students who utilized ALEKS, graduating class of 2021, to analyze the second research question. A correlation test was conducted on the minutes spent in ALEKS by a student and the student's math ACT, t(213) = 10.473,

$p < .001$. with a 95% confidence interval of (0.487, 0.665). A correlation of $r = .583$ was observed, signifying a positive moderate linear correlation between minutes a student spends in ALEKS and their math ACT score.

Figure 10: Scatterplot of Minutes in ALEKS over Math ACT scores



Teacher B and Teacher F had slightly higher correlations, $t(53) = 5.60$, $p < .001$, $r = .610$ and $t(24) = 4.02$, $p < .001$, $r = .635$, respectively. Interestingly, three teachers had weekly ALEKS goals the students were required to meet, whereas the other teachers had quarterly or biquarterly goals, Teacher B and Teacher F were two of the three teachers that had weekly ALEKS goals for their students.

An ANOVA of the linear model was conducted, Table 13, to examine correlation analysis when adding a student's algebra AIR score and a student's geometry AIR score. Table 14 below shows the corresponding coefficient of determination for each factor.

Table 13

ANOVA of Math ACT scores, Predicted by Algebra AIR score, Geometry AIR score, and minutes a student spend in ALEK

	Df	Sum of Squares	Mean Square	F	p - value
Algebra AIR	1	2063.64	2063.64	313.591	$p < .001$
Geometry AIR	1	492.00	492.00	74.764	$p < .001$
Minutes in ALEKS	1	283.63	283.63	43.101	$p < .001$
Residuals	211	1388.52	6.58		

Table 14

Coefficient of Determination

	Algebra AIR	Geometry AIR	Time in ALEKS
Coefficient of Determination, R^2	.488	.116	.067

When including the student's previous abilities on the algebra AIR test and the geometry AIR test, only 6.7% of the variance in the Math ACT score is explained by the regression on their time spent in ALEKS. While ALEKS appears to help students recall previously learned information and improve a student's math ACT score, it is apparent through higher coefficients of determinations that a student's initial exposure and understanding of the material plays a vital role in a student's math ACT score and cannot be replaced with the use of ALEKS.

A linear model was created with the predictors graphed over the residuals as illustrated in Figures 11, 12, and 13 to ensure linearity. The fitted values were also graphed over the residuals to ensure homogeneity of variances. The graph does show some concern that there may be some outliers within the data that do not have homogeneity of variances, Figure 14.

Figure 11: Algebra AIR scores graphed over the residuals

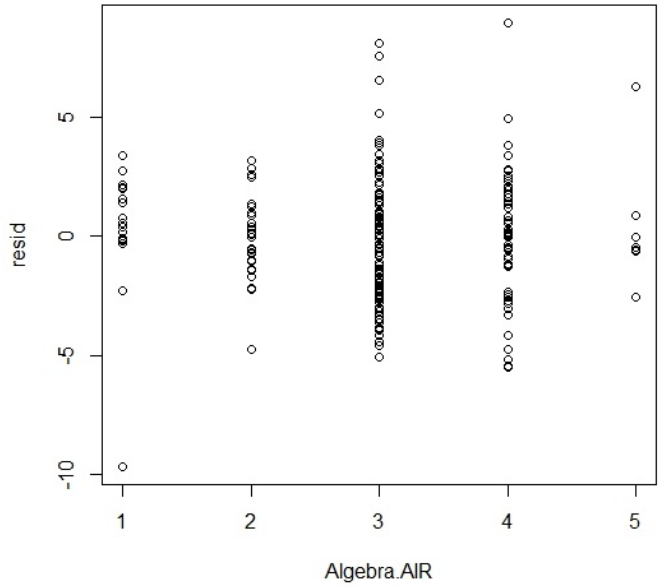


Figure 12: Geometry AIR scores graphed over the residuals

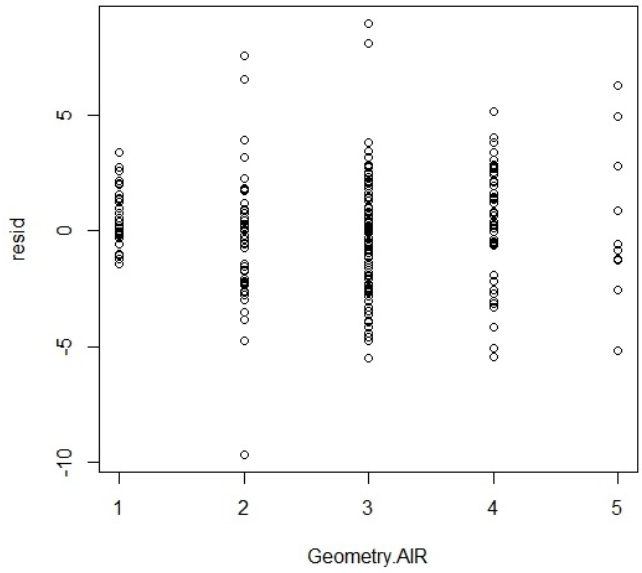


Figure 13: Minutes in ALEKS over the residuals

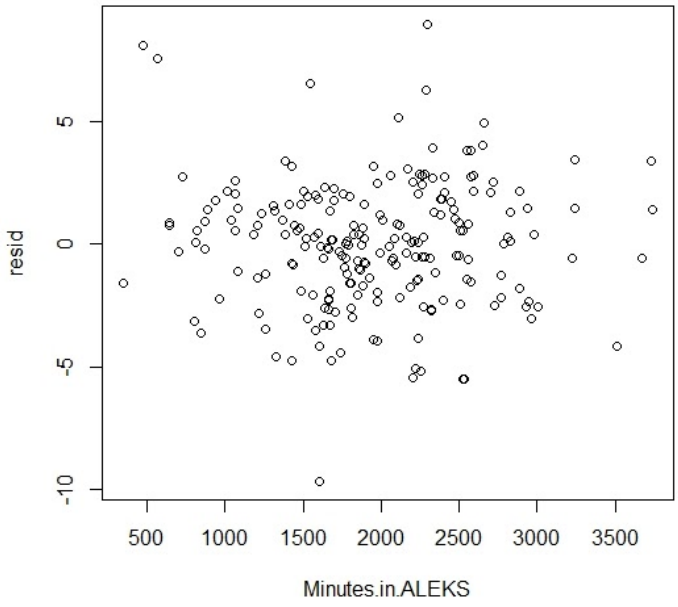
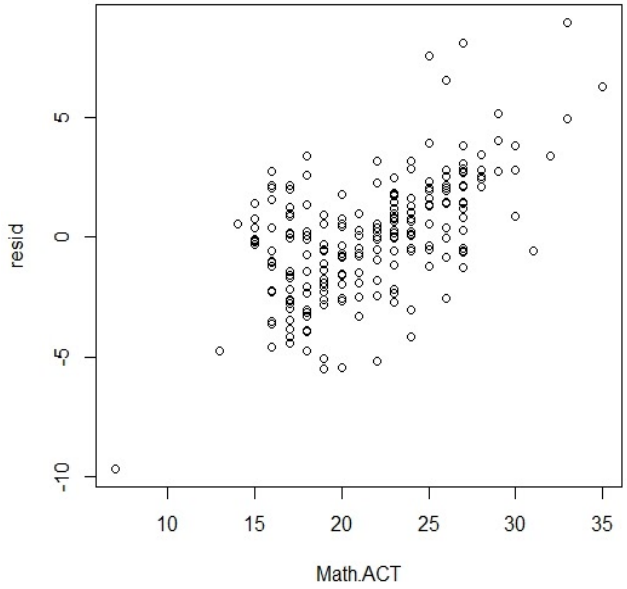


Figure 14: Math ACT scores over the residuals



To ensure a normal population a histogram of the residuals was created, Figure 15. A QQ Plot was also constructed, Figure 16. The histogram and the QQ Plot both suggest potential outliers in the data. The QQ Plot has points at both tails that fall far from the line suggestion that the data set may have some extreme outliers.

Figure 15: Histogram of Residuals

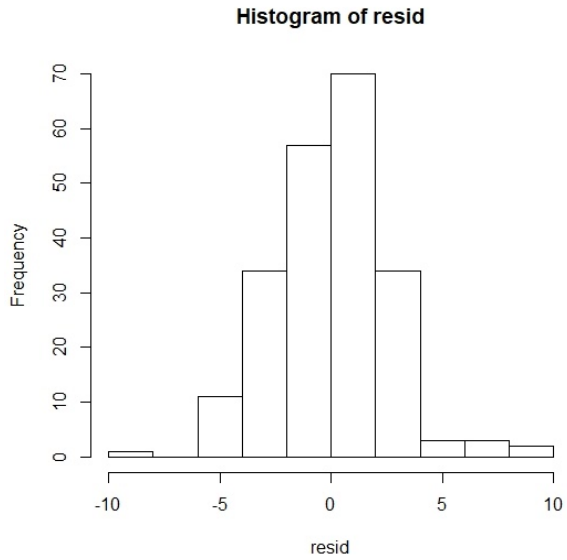
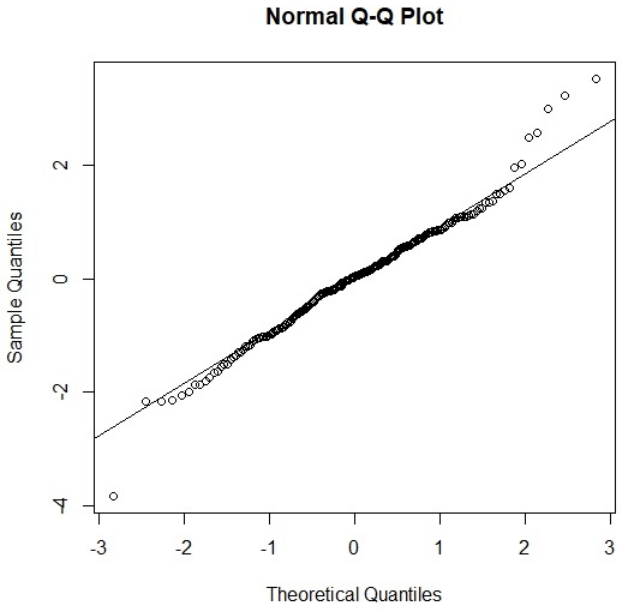


Figure 16: QQ Plot



The Durbin Watson test was run to ensure independence, with DW = 1.729, p = .12. The variance inflation factor was also run to ensure multicollinearity, the results are listed in Table 15.

Table 15 Variance Inflation Factors

	Algebra AIR	Geometry AIR	ALEKS
VIF	2.05	2.17	1.26

A regression model was conducted, Table 16, along with the corresponding confidence intervals for each variable, Table 17. The regression model reveals, while controlling for a student's Algebra AIR score and a student's Geometry AIR score, a student's math ACT score increases .002 with each minute spent in ALEKS.

Table 16

Multiple Regression Analysis

	Estimates	Standard Error	t value	p - value
Intercept	8.699	.677	12.839	$p < .001$
Algebra AIR	1.442	.262	5.511	$p < .001$
Geometry AIR	1.618	.224	6.645	$p < .001$
Minutes in ALEKS	0.002	.0003	6.565	$p < .001$
	$F(3, 211) = 143.8$, $p < .001$		Adjusted R^2 =.667	

Table 17

Confidence Intervals

	Lower	Upper
Intercept	7.36	10.03
Algebra AIR	.93	1.96
Geometry AIR	1.14	2.10
Minutes in ALEKS	.001	.003

The standard residuals were further examined and Case 8, Case 15 and 17 were found to have standard residual values of -3.83, 3.00 and 3.23 respectively. All three cases had an absolute value greater than three and were deemed outliers and removed from the data set. An additional regression model was run without the outliers, Table 18, and the corresponding confidence intervals, Table 19.

Table 18

Multiple Regression Analysis without Outliers

	Estimates	Standard Error	t value	p - value
Intercept	7.292	.636	13.438	$p < .001$
Algebra AIR	1.226	.244	5.016	$p < .001$
Geometry AIR	1.655	.225	7.345	$p < .001$
Minutes in ALEKS	0.002	.0003	8.080	$p < .001$
	$F(3, 208) = 168, p < .001$		Adjusted R^2 =.704	

Table 19

Confidence Intervals

	Lower	Upper
Intercept	7.29	9.80
Algebra AIR	0.74	1.71
Geometry AIR	1.21	2.10
Minutes in ALEKS	0.0018	0.003

The regression model without the outliers revealed a higher adjusted R^2, providing a better linear regression model of the data. Students were given a goal of at least 60 minutes in ALEKS per week. From the start of school to the end of February when students take the ACT there are 25 weeks of school, the regression model suggests that a student who worked diligently in ALEKS and completed their 60 minutes each week could raise their math ACT score by 3 points.

Summary

The purpose of this chapter was to describe the participants of the study, how data was received, and analyze the data to answer the two research questions.

With permission from the administration of Pickerington High School North the results of the junior and seniors Algebra AIR score, Geometry AIR score, and Math ACT score was analyzed to determine if the use of a three tier ALEKS program is helping students recall and retain previously taught mathematical material as assessed on the

math portion of the ACT. The administration cleansed the data prior to analysis so that there was no identifiable information to ensure privacy for each student.

An ACOVA, controlling for the student's Algebra AIR score and their Geometry AIR score, revealed a statistically significant increase when students utilized ALEKS. The regression model revealed, when controlling for a student's Algebra AIR score and Geometry AIR score, the use of ALEKS increases a student's Math ACT score by 1.756. The post hoc analysis revealed, while the utilization of ALEKS does increase a student's Math ACT score, the student's initial exposure, as assessed by the student's Algebra AIR and Geometry AIR score, also plays a key role in the student's Math ACT score.

When examining the correlation of minutes in ALEKS to the student's Math ACT score a moderate correlation is achieved, however when a student's Algebra AIR score and Geometry AIR score is included we find the minutes spent in ALEKS only explains 6.7% of the variance in Math ACT scores. A regression analysis reveals a coefficient of .002 for minutes spent in ALEKS, revealing that if a student spends the required 60 minutes a week for 25 weeks leading up to the ACT, they can improve their math ACT score by 3 points.

CHAPTER V: SUMMARY

This chapter will summarize the results of the current study, discuss the limitations of the current study, and examine possible future studies.

Math teaches fundamental skills utilized in most careers. With the advancements in technology around the world, The United States Department of Education ("Science, Technology, Engineering, and Math, including Computer Science"), notes the importance and need for strong mathematical and problem solving skills is only increasing, however each year, the ACT is finding, high school graduates readiness for college level math is decreasing (act.org). A deficit in mathematical ability is leading to many students being placed in remedial math courses as they enter college, with a high proportion of those students being African American. The effects of remedial courses have shown to be detrimental to a student's ability to graduate college and as a result colleges and universities are looking for ways to help students gain the mathematical knowledge needed to be successful in college, without being stuck in a never-ending cycle of costly remedial courses. (Hanford, 2016)

With permission of the administration at Pickerington High School North, ACT math results for the graduating class of 2020 and 2021 will be examined to determine if the usage of a three tier ALEKS program with the graduating class of 2021 has improved mathematical retention and resulted in an increase of the schools mean ACT math score. The student's AIR Algebra and AIR Geometry scores, both of which were administered prior to the implementation of the three tier ALEKS program, will be utilized as a covariate to ensure one graduating class did not have a stronger mathematical understanding. An analysis will also be conducted to see if the number of minutes spent

in ALEKS can predict a student's ACT score. Data will be cleansed prior to being received from the administration of Pickerington High School North to ensure all identifying information is removed from the data maintaining the confidentiality of all participants and their math scores.

Summary of the Results

The results from the study revealed a statistically significant difference between the Math ACT scores, for both the seniors and juniors, between the different races (Table 2 and Table 5, Chapter 4). The Bonferroni post hoc test revealed, for both seniors and juniors, statistical significance between Caucasian and African American students with a large effect size for the seniors and a moderate effect size for the juniors. While the level of statistical significance and the effect size did lower, for the difference in Caucasian and African American achievement with the juniors who utilized ALEKS, there is still an achievement gap between Caucasian and African American students at Pickerington High School North.

A statistical significance between the minutes spent in ALEKS also emerged between the Teachers (Table 7, Chapter 4). A Bonferroni post hoc test revealed statistical significance between Teacher D and four other teachers, Teacher A, Teacher B, Teacher E, and Teacher F. All students were given a goal of 60 minutes per week in ALEKS, Teacher D's students spent an average of 2763.23 minutes in ALEKS over the course of the 25 weeks leading up to the ACT test, which equates to an average of 110.57 minutes per week, nearly double the student's weekly goal. The increased time was not mandated by Teacher D, and resulted from a group of strongly driven and highly motivated

mathematical students in Honors PreCalculus who elected to spend more time than required in ALEKS each week.

Summary of Results for Question 1

Question 1: Will statistically significant differences emerge in mean math ACT sub scores for students at Pickerington High School North who did not use ALEKS to prepare for the math portion of the ACT when compared with students who did use ALEKS to prepare for the math portion of the ACT when controlling for results from the AIR math test?

ANCOVA techniques were used to examine Math ACT scores across the use of ALEKS (used or did not use) while controlling for the student's previous Algebra AIR score and Geometry AIR score. Statistical significance emerged with the juniors, who used ALEKS, scoring statistically higher on the math portion of the ACT as compared to the seniors who did not use ALEKS during the year the ACT was administered to them. In previous studies Lomibao (2017) and Kang (2016) both found repetition and varied practice provided an increase in student retention on teacher given assessments. ALEKS provides both repetition and varied practice, the results of this study concur with the results of Lomibao and Kang that repetition and varied practice increases a student's retention with this study taking the results a step further and examining the increased effects on standardized testing.

Further examination of the results of this study revealed African American students had the largest statistically significant growth in their mean math ACT score when utilizing ALEKS. Caucasian students also showed statistical significance with the

use of ALEKS however the statistical significance was not as high. The results revealed a gap between the achievement of African American and Caucasian students on the math portion of the ACT. ALEKS was effective in assisting the African American students, at Pickerington High School North, in shrinking the achievement gap., however the gap is not closed. These results are similar to the results found by Cheney (2011); both studies found ALEKS helped in closing the achievement gap between Caucasian and African American students, but did not close the gap and more work and intervention will need to be put in place to ensure all students have an equal educational opportunity.

A QQ plot revealed a few points on the top of the tail that were possible outliers. Further examination of the standard residuals revealed two cases were deemed outliers and removed from the data set. A second regression model was run (Table 11, Chapter 4) and revealed a R2=66.0%, thus revealing 66.0% of the variance in Math ACT scores is explained by the regression on Algebra AIR scores, Geometry AIR scores, and the use of ALEKS. The regression model also revealed, while controlling for a student's Algebra AIR score and a student's Geometry AIR score, a student's Math ACT score increases 1.756 with the use of ALEKS. In controlling for a student's Geometry AIR score and the use of ALEKS, a student's Math ACT score increases 1.460 with each unit increase in their Algebra AIR score. In controlling for a student's Algebra AIR score and the use of ALEKS, a student's Math ACT score increases 2.183 with each unit increase in their Geometry AIR score. While the use of ALEKS is shown to have an increase effect in a student's math ACT score, the regression analysis shows that a student's initial understanding of algebra and geometry as assessed on the AIR test, which has a score

range of 1 to 5, plays a stronger role in determining a student's achievement on the math portion of the ACT.

Summary of Results for Question 2

Question 2: Will minutes spent on ALEKS correlate significantly with the math ACT sub score?

A correlation test conducted on the minutes spent in ALEKS by a student and their math ACT score revealed a correlation of r = .583 signifying a positive moderate linear correlation between the minutes spent in the ALEKS and a student's math ACT score. Each student was given a goal of 60 minutes a week in ALEKS. Three teachers opted to also give the students weekly ALEKS topic goals to ensure they met and maintained their 60 minutes a week, the other teachers opted for quarterly or biquarterly topic checks. Two of the three teachers that required weekly topic goals, Teacher B and Teacher F, had slightly higher correlations. While their correlations were still only moderate, it appears weekly checks to help hold the students accountable, may create a stronger correlation between their time spent in ALEKS and their math ACT score.

An ANOVA was conducted of the linear model of a student's Math ACT score predicted by their Algebra AIR score, Geometry AIR score, and minutes spent in ALEKS (Table 11, Chapter 4), resulting in Algebra AIR, Geometry AIR, and minutes spent in ALEKS having a coefficient of determination of 48.8%, 11.6%, and 6.7% respectively. When including a student's previous abilities on the Algebra AIR test and the Geometry AIR test, only 6.7% of the variance in their Math ACT score is explained by their time spent in ALEKS, whereas their Algebra AIR score and Geometry AIR score explains 48.8% and 11.6%, respectively. While ALEKS appears to help student's recall and/or

expound on previously learned material and improve their math ACT score, the student's initial exposure and understanding of the material plays a vital role in the student's math ACT score and cannot be replaced by the use of ALEKS.

A QQ plot (Figure 16, Chapter 4) revealed a few values at both ends of the tails that were possible outliers skewing the data. An examination of the standard residuals found three cases to have standard residual values greater than the absolute value of three and were deemed outliers and removed from the data set. The regression model was then run (Table 16, Chapter 4) and revealed a R2=70.4%, thus revealing 70.4% of the variance in Math ACT scores is explained by the regression on Algebra AIR scores, Geometry AIR scores, and the minutes spent in ALEKS. The regression model also revealed, while controlling for a student's Algebra AIR score and a student's Geometry AIR score, a student's Math ACT score increases .002 with each minute they spend in ALEKS. The junior's average ACT score rose to 21.64 with the use of ALEKS, as compared to the senior's average of 19.87 without the use of ALEKS. ACT sets 22 as the mathematical benchmark for college readiness. A study at Utah Valley University found the use of ALEKS eliminated the need of remedial math for a majority of their students, while the finding of this study is similar, and less juniors would be required to take a remedial math course as compared to the seniors, the results are not as promising as those found at Utah Valley University.

Limitations

The study was conducted at Pickerington High School North, a suburban district that is currently the 15th largest district in the State of Ohio, with over 10,600 students and where the median house price is $209, 225. ("About Our Community") According to

the latest State of Ohio school report card, released in September 2019, the district contains 57% white non-Hispanic students, 25.5% black, 7.7% multiracial, 5.4% Hispanic, and 4.4% other. Within the district 28.2% of the students are economically disadvantaged, as they qualify for the USDA National School Lunch Program. ("School Report Card") While Pickerington High School North, demographically, is similar to many of the suburban schools in the Columbus, Ohio area, this study may not resemble all school districts across the United States, and thus the results may not be the same for all school districts. Pickerington Local Schools is also a one-to-one district, where each student is given a chromebook to utilize throughout the school year. Families that do not have Wi-Fi are able to borrow a hotspot from the district to ensure all students have internet access for their chromebooks while at home. Districts where technology is not as readily available may not be able to implement ALEKS to the same extent, and thus may have different results. In order to gain a better understanding of the success of ALEKS in improving a student's mathematical retention, a larger study encompassing a wide variety of school districts including urban, suburban, and rural, with differing racial and socioeconomic breakups should be conducted.

In review of the current study, the students went through a three course ALEKS progression. The students all started in a high school prep course, which consists of pre-algebra and beginning algebra skills. Once the student mastered 70% of the content, they moved to the second course, an algebra review course, which includes key algebra skills along with coordinate geometry skills. Again, when the student mastered 70% of the content they moved to their final course, which was the content course. While these skills overlap the skills that are assessed on the math portion of the ACT, the questions are not

directly aligned and written in the same manner as the ACT. ALEKS does offer an ACT course which is directly aligned with the ACT and mimics the formatting of the ACT questions, implementation of this course rather than the three course progression may lead to greater retention of a student's mathematical knowledge and thus greater improvement in a student's math ACT score, further study would need to be conducted.

Future Studies

The current study assessed whether the three course ALEKS progression improved a student's mathematical retention as assessed on the math portion of the ACT. Pickerington High School North has all students completing the three course progression starting their freshman year in Algebra. The last course, in the ALEKS three course progression is the content course, thus the last course for the algebra students is an ALEKS algebra course and the last course for the geometry students is an ALEKS geometry course, both of which are aligned to the State of Ohio mathematical course standards that are assessed on the Algebra AIR and Geometry AIR assessments. Future studies on whether the ALEKS algebra and ALEKS geometry course help improve a student's Algebra AIR score and Geometry AIR score should be conducted.

The current study also did not include all juniors and seniors as students enrolled in AP courses or CCP courses during their junior year were not enrolled in ALEKS and therefore were not included in the study. All students, in the State of Ohio, are required to take the Algebra AIR assessment and the Geometry AIR assessment. If the district were to implement ALEKS for all students in algebra and geometry, including those in junior high, they could assess the effects of ALEKS on a student's Algebra AIR score and Geometry AIR score and gain a more encompassing picture of the effects ALEKS is

having on mathematical retention for all students in the Pickerington Local Schools District. In addition, including all students could lead to a more accurate analysis of the mathematical achievement gap between the different races and the ability ALEKS has on closing the achievement gap for all students could be examined.

Summary

The purpose of this chapter is to summarize the results of the current study, the limitations of the current study, and examine possible future studies.

An ANCOVA on Math ACT scores across the use of ALEKS, while controlling for the student's Algebra AIR score and Geometry AIR score, revealed the use of ALEKS was statistically significant in improving a student's Math ACT score, however the regression analysis shows that a student's initial understanding of algebra and geometry, as assessed on the AIR test, plays a stronger role than the use of ALEKS in determining a student's achievement on the math portion of the ACT. A statistically significant achievement gap between Caucasian and African American students is prevalent in the senior's (control group) Math ACT scores, the use of ALEKS lowered the achievement gap in the junior's (experimental group) Math ACT score and the level of statistical significance but did not eliminate the achievement gap.

A correlation test revealed a positive moderate correlation between the minutes a student spends in ALEKS and the student's Math ACT score. A linear regression analysis further determined a student's Math ACT increase .002 with each minute the student spends in ALEKS. Students were given a goal of at least 60 minutes in ALEKS per week, there were 25 weeks from the start of the school year to the end of February when the ACT was administered, the regression model suggests that a student who worked

diligently in ALEKS and completed their 60 minutes each week could raise their math ACT score by 3 points.

This study was conducted in Pickerington Local Schools, a suburban school district of Columbus, Ohio. The district is a one - to - one school district that provides chromebooks for all students and Wi-Fi connections for those households that do not currently have Wi-FI connection. Results for other districts that do not have a similar student population and/or do not have the same access to technology may vary greatly. Further studies on the effectiveness of ALEKS in increasing a student's mathematical retention will need to be conducted on a wider variety of school districts and student populations. In addition, further study should be conducted on the effectiveness of ALEKS in increasing a student's mathematical retention on other high stakes testing such as end of course AIR assessments.

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Appendix A: IRB Application and Approval

For Office Use Only

Shawnee State University Protocol #

Expedited and Full Review Application

Title of Research Project: Does the implementation of ALEKS increase high stakes test scores such as the ACT.

Name(s) of Principal Investigators:	Email address:	Faculty	Student	Other
Pamela Waits	waitsp@mymail.shawnee.edu	☐	X	☐
Doug Danbro	ddanbro@shawnee.edu	X	☐	☐
		☐	☐	☐
		☐	☐	☐
		☐	☐	☐
		☐	☐	☐

*Please place an asterisk by the investigator name(s) whose NIH certificate(s) is/are already on file with the IRB, if the certificate is less than 3 years old.

Contact Name: Pamela Waits Contact Phone Number: 614-316-6306

Department(s)/Division/Agency: Masters of Mathematical Science Program

1. Describe the key demographics (age, SES, ethnicity, geographic locations, gender, etc.) of the sample that you wish to obtain.

High school students (juniors and seniors) currently enrolled in Pickerington High School North, a suburb of Columbus, Ohio.

1a. What is the greatest number of participants that will be recruited? 900

1b. How will participants be recruited? Students are already enrolled in the district, their scores for the AIR algebra, AIR geometry, and math ACT will be analyzed.

1c. Check the type of populations listed below that will be included in the study.

__X__ Children (under the age of 18)
_____ Prisoners
_____ Participants with diminished cognitive ability
_____ Pregnant women and/or fetuses
_____ No vulnerable populations will be included

2. Will participants be remunerated for their participation? Yes No - X

2a. If so, how will participants be remunerated? Please indicate the type of remuneration and the amount. For instance, the participants will be given a $10 Amazon Gift Card for participation or the participants will receive 3% of their final grade in extra credit in their Introduction course. _____

_____N/A_____

_____

2b. If participants do not complete the study, will partial or full remuneration be given? Please describe how that will be determined. _____

_____N/A_____

_____

3. What direct benefits (other than remuneration) exist for the participants who participate?

The benefits are for the school district as a whole, to see whether ALEKS is helping the students.

_____

4. What direct risks could the participants potentially face? Check all that apply.

_____ Risk of breach of confidentiality or privacy

_____ Risk of coercion by researcher(s)

_____ Risk of psychological harm

_____ Risk of physical harm

_____ Other potential risk: _____

4a. Please describe the specific risk(s). _The scores are part of district records. The district will cleanse the data so that there is no identifiable information and thus no risk to the individual students. _____

4b. What measures will be taken to limit or minimize the risks? _The data is being cleansed by administration prior to me obtaining it, so that no identifiable information is associated with the scores. _____

5. What are the expected benefits of the research to the scientific community or the common good?

School districts are always looking for ways to help students retain knowledge and fill in gaps in their mathematical knowledge. This study could provide evidence whether or not adaptive learning programs are beneficial in high school math courses.

6. Does the methodology require that participants be deceived about any aspect of the study?

Yes No - X

6a. If so, please justify the use of deception and describe the debriefing procedures that will be used (Please attach the debriefing form and/or a script of the debriefing information).

N/A

7. How will the participants be informed of the risks and benefits of the study?

The district maintains the scores of the students as part of their records. The district has agreed to cleanse the data so there is no risk to the students. In addition, as a Pickerington Local School district employee I have signed a contract to maintain student confidentiality of any student data that I may come in contact with.

7a. How will consent be obtained from participants (or their legal guardian)?_

The district currently maintains the AIR scores and ACT scores as part of their records. District administration has agreed to the study. A signed consent form from the principal of Pickerington High School North is included.

7b. Will participants be involved who cannot give legal consent? Yes No - X

7c. If so, how will assent be obtained from the participants? _____

N/A

8. Based on the "What type of review" form, I believe that my research project only requires an expedited review.

(Yes) No

In submitting this form and the corresponding documents, I acknowledge that I have completed Human Research Participants training and that I understand and will uphold the rights of human participants. I also verify that all information contained in this form and any other corresponding documentation is correct based on my knowledge. I understand that I may not have contact with any research participants until the Shawnee State University IRB has given me their approval. I also understand that I must file a ***Continuing Review Form*** if my project extends beyond a year from my approval date and I must file a ***Study Completion Report*** with all consent forms once the study is complete.

Pamela Ward
Signature of Principal Investigator 1

Signature of Principal Investigator 2

Signature of Principal Investigator 3

Signature of Principal Investigator 4

Signature of Principal Investigator 5

Signature of Principal Investigator 6

Date of Submission: 10/30/19

Consent Form for Participation in a Research Study
Shawnee State University

1. Study Title: Does the implementation of ALEKS increase high stakes test scores such as the ACT

2. Performance Site: Pickerington High School North

3. Investigators: Pamela Waits

4. Purpose of the Study: To examine if math ACT scores improve with the implementation of ALEKS

5. Subject Inclusion: The test scores of Pickerington High School North Juniors and Seniors

6. Number of subjects: Maximum 900 students

7. Study Procedures: The data is currently part of district records. The data would be cleansed prior to receiving the data from the district to ensure there is no identifiable information, and then statistical analysis would run to determine if ACT scores did improve with the implementation of ALEKS.

8. Benefits: School districts are always looking for ways to help students retain prior knowledge and fill in gaps in their mathematical knowledge. The study could provide evidence whether or not adaptive learning programs are beneficial in the high school math courses.

9. Risks: The data will be cleansed of any identifiable information prior to receiving the data from the district therefore there will be no risk to the individual student.

10. Right to Refuse: Subjects may choose not to participate or to withdraw from the study at any time without penalty or loss of any benefit to which they might otherwise be entitled.

11. Privacy: Results of the study may be published, but no names or identifying information will be included in the publication. Participant identity will remain confidential unless disclosure is required by law. All documents will be stored in (describe secure or locked location) for a period of 3 years, at which point the documents will be destroyed.

12. Signatures: I verify that I am 18 years of age or older. The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators listed above. If I have questions about subjects' rights or other concerns, I can contact Becky Thiel, Acting Associate Provost, Institutional Review Board, (740) 351-3017. I agree to participate in the study described above and acknowledge the investigator's obligation to provide me with a signed copy of this consent form.

Signature of Subject Mark Mull Date 10/29/19

Pickerington North Principal

Re: IRB Application

IRB <irb@shawnee.edu>
Mon 12/16/2019 2:54 PM
To: Pamela Waits <waitsp@mymail.shawnee.edu>

Good evening, Pamela,

I'm sorry for the delay; there was confusion in communicating with your reviewer. Your application has been approved.

Sincerely,
Dr. Hamilton
IRB Chairman

BIBLIOGRAPHY

Pamela S. Waits

Candidate for the Degree of

Master of Science Mathematics

Thesis: DOES ALEKS HELP WITH MATHEMATICAL RETENTION AS MEASURED ON THE ACT

Major Field: Mathematics

Education: Bachelor of Arts in Mathematics

Completed the requirements for the Master of Science in Mathematics, Portsmouth, Ohio in July 2020.

Douglas G Darbro 7/20/2020

ADVISER'S APPROVAL: Dr. Douglas Darbro