UNDERSTANDING TEACHERS' PERCEPTIONS AND STRATEGIES IMPLEMENTED IN HIGH SCHOOL MATHEMATICS CLASSES USING ALEKS

by

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ABSTRACT

The Assessment and Learning in Knowledge Spaces (ALEKS) is an adaptive learning tool used by hundreds of thousands of high school students in the United States. This study was designed to understand how teachers in high school mathematics classrooms used the ALEKS system for instruction and to examine what their perceptions were of its ease of use and usefulness. A basic qualitative study was conducted where five Chicagoland high school mathematics teachers were interviewed three times over the course of one academic school year. This study asked teachers to share first hand experiences and perceptions of using ALEKS. The Technology Acceptance Model (TAM) served as the theoretical framework for examining these experiences and perceptions.

The results of this study indicate a variety of teaching strategies that teachers used with ALEKS as well as many common themes. Teachers used the ALEKS tool for assessing student understanding through its quizzes and assignments, used the data analysis tools with the program to analyze student progress, and made use of ALEKS to allow students to practice and receive feedback on mathematical concepts. The findings of this study indicate that teachers found ALEKS to be easy to use and useful in their teaching. Specifically, teachers cited the assessment tools, built-in feedback, ability to personalize learning, and the accessibility of learning tools for students as useful in their teaching.

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LIST OF ABBREVIATIONS

ALEKS	Assessment and Learning in Knowledge Spaces
CBI	Computer-Based Instruction
NCTM	National Council of Teachers of Mathematics
TAM	Technology Acceptance Model
TEL	Technology Enhanced Learning
TRA	Theory of Reasoned Action

CHAPTER 1: INTRODUCTION

Introduction

Adaptive learning tools are data-driven systems able to meet the individual needs of students by adjusting instruction based on student behaviors and competencies (Bulger, 2016). One such tool, the Assessment and Learning in Knowledge Spaces (ALEKS), is used by millions of students across the country (ALEKS, 2020b). Although this tool has a significant number of students using it to learn mathematics, there is no clear evidence of its effectiveness. There have been favorable studies with results that have shown its use for improving academic performance (Goodwin, 2017; Karner, 2016; Yilmaz, 2017), but there have also been studies that suggest that its impact is negligible (Mills, 2018; Nwaogu, 2012; Richard, 2019). Add this to the fact that there has been limited research on exactly what strategies teachers use with ALEKS and what their perceptions are of this tool.

The goal of this research study was to learn how teachers in high school mathematics classrooms used the ALEKS system for instruction and to examine what their perceptions were of its ease of use and usefulness. This research followed a basic qualitative design in which five high school mathematics teachers were interviewed three times throughout an academic school year. This study adds to the research concerning the impact of using adaptive learning tools in high school settings and fills gaps in the research by providing evidence of teachers' perceptions of these tools. It provides valuable information for future research related to the use and design of adaptive learning tools; and schools, teachers, and technology companies can use the results of this research to find ways to improve technology implementation and to find success teaching high school-level mathematics.

Background of the Study

There has been a significant amount of research devoted to finding a relationship between teaching strategies and academic success in mathematics (Anthony & Walshaw, 2009; Caro et al., 2016; NCTM, 2020b). The research has shown that effective teaching strategies such as a focus on higher-order thinking skills, classroom management strategies, and the feedback techniques have been some of the most influential factors in determining success of a student in a mathematics classroom (Anthony & Walshaw, 2009; Bartell et al., 2017; Caro et al., 2016; Hattie & Timperley, 2007; NCTM, 2020c; Shute, 2008). There also have been studies devoted to the role technology plays in academic success, with evidence suggesting that it improves the teaching of mathematics by allowing for more efficient methods of calculation, graphing, modeling, and data analysis (Sen & Ay, 2017; Wachira & Keengwe, 2011). Literature has also suggested that technology can provide better feedback to students and enhance engagement (De Witte & Rogge, 2014; Hattie, 1999; Ra, Chin, & Lim, 2016; Roschelle et al., 2010). The body of evidence supporting the use of effective teaching strategies in the mathematics classroom and the potential benefits of technology implementation in that space is substantial, but there is still a need for more specific research related to modern technologies like adaptive learning systems.

The research on adaptive learning systems has only spanned the past few decades and has been constantly evolving as new technologies emerge with more sophisticated capabilities. The most current research has suggested that the use of adaptive learning systems can be beneficial when used as an intervention or as a supplement to other teaching strategies (Bochniak, 2014; Burns et al., 2012; Cheung & Slavin, 2013; Longnecker, 2013). However, other research has shown mixed results, with some studies showing improvements in measures like test scores while others have not shown much of an impact (Campuzano, 2009; Hollands & Pan, 2018; Kelly, 2018). What is lacking in the literature regarding adaptive learning tools is the way in which teachers use the tools and an examination of their perceptions of its ease of use and usefulness.

As a high school mathematics teacher, the researcher has used adaptive learning tools such as ALEKS in his classroom. His colleagues have also used ALEKS and other adaptive learning tools in various capacities. Part of what interested the researcher in conducting this study was the different ways and levels of success teachers had with using ALEKS. Some teachers would just give the access codes out to students and expect them to use the tools properly while others would attempt to integrate it in their classroom. When exploring the literature related to ALEKS and adaptive learning tools the researcher did not find many resources that discuss the teaching strategies used or the perceptions of teachers using ALEKS.

This study fills gaps in the current research related to adaptive learning tools and teaching mathematics with technology. There has been a limited amount of research that has attempted to determine teaching strategies using adaptive learning systems (Azevedo et al., 2005; Benjamin, 2020). Most studies have attempted to measure student success based on improvements in test scores, but have failed to provide any information regarding the pedagogy of the teacher while implementing the tool. In this study, the researcher has helped to reduce the gap by collecting qualitative data on the way teachers used the ALEKS system during an academic school year.

Purpose of the Study

The purpose of this study was to understand what teaching strategies high school mathematics teachers used with the ALEKS system and to examine their perceptions of its ease of use and usefulness. For this study, qualitative data were collected at the level of implementation, including teaching strategies, and perceptions of high school mathematics teachers that used ALEKS. To collect this data, teachers who participated in this study were interviewed three times throughout an academic school year.

This study utilized qualitative research to better understand how ALEKS is used in high school mathematics classrooms. Most of the research about ALEKS has used quantitative measures like test scores to assess its impact (Bochniak, 2014; Burns et al., 2012; Campuzano, 2009; Cheung & Slavin, 2013; Hollands & Pan; Kelly, 2018; Longnecker, 2013). However, these studies did not account for other variables that may impact their results, such as the teaching strategies used and the teachers' perceptions of ALEKS's ease of use and usefulness. This study helps to fill the gaps in adaptive learning and ALEKS research by providing qualitative data regarding its use.

Research Questions

This study helps to fill the gaps in the research on adaptive learning tools by examining the ways in which ALEKS is used and perceived by high school mathematics teachers. There have been few studies attempting to analyze how ALEKS is used by teachers in classroom settings. There have also been few studies that specifically address the perceptions of teachers who are using ALEKS for their course. This study aimed to answer the following research questions:

1) What teaching strategies are high school mathematics teachers implementing while using the adaptive learning tool, ALEKS?
2) How do high school mathematics teachers perceive the ease of use of the adaptive learning tool, ALEKS in their classrooms/classes?
3) What are high school mathematics teachers' perceptions of the usefulness of the adaptive learning tool, ALEKS in high school mathematics classes?

These questions guided the core components of this study and helped to provide the evidence missing from the research related to adaptive learning tools. The research questions presented in this study were answered by following a basic qualitative research design where data was collected regarding the rationale for teachers' decisions and perceptions. The data collection process was performed through interviews with teachers who used ALEKS in their mathematics classes.

Significance of Study

The focus of this qualitative study was to capture the voices of actual high school mathematics teachers who used ALEKS and to analyze the data collected about the way in which they used the tool in their classrooms. This study contributes to the field of research related to adaptive learning tools. Also, the findings of this research have practical applications for schools, teachers, and technology companies.

Much of the research that has been conducted about ALEKS focuses on its effectiveness for student learning as measured by assessments in quantitative studies that used quasi-experimental designs (Karner, 2016; Mills, 2018; Yilmaz, 2017). There have been few studies that explored the teaching strategies used with ALEKS in a classroom setting (Padilla-Oviedo et al., 2016; Serhan, 2017; Wang et al., 2018). There has also been little research focused on teachers' experiences using ALEKS or on their perceptions on its ease of use and usefulness. This research study contributes to the literature as one of the few attempts to use teachers' voices in an attempt to understand the use of adaptive learning tools in mathematics classrooms. The results of this study may influence other researchers to use teachers' voices to analyze the implementation of adaptive learning tools in classrooms.

The results of this study may also have practical implications for schools. Given the already widespread use of adaptive learning tools, it is likely that many high schools are either using some form of the technology already or will have access to it in the near future (ALEKS, 2020; Molnar, 2017). The research has shown that successful technology integration requires schools to be supportive of its use and requires teachers to be well-trained on the tools (Goos & Bennison, 2008; Karatas et al., 2017; Pierce & Ball, 2009; Wachira & Keengwe, 2011). Proper training and professional development help teachers to establish confidence in their use which facilitates better technology integration (Karatas et al., 2017; Pierce & Ball, 2009; Wachira & Keengwe, 2011). The results of this study provide school administrators with accounts of the experiences and perceptions of teachers so that they can plan effective training and support for teachers. Teachers could use the results of this study to gain an understanding of how their colleagues have used ALEKS, so they can plan ways to implement the system in their classrooms. Since this study provides accounts from actual teachers regarding their perceptions of the tool's usefulness, it could provide school leaders with relevant information they may need to make informed decisions related to technology expenditures and curriculum.

Schools are not the only setting that the results of this study could have an impact in. Technology companies that provide adaptive learning tools could use the information from this study to find more effective ways to provide additional support for teachers. This support could educate users on how to use the tool or could educate users about the teaching strategies that enhance its use. Some companies like ALEKS already offer teacher guides and suggestions for how to use their technology in various classroom settings (ALEKS, 2020c). This study, however, provides research from an independent source.

Theoretical Foundations

This study followed the Technology Acceptance Model (TAM). TAM was developed by Davis (1989) and has become one of the models most widely used to predict the use of a technology tool (Davis & Venkatesh, 1996; Sauro, 2019; Yousafzai, Foxall, & Pallister, 2007). Numerous studies have used this model (or an altered version of it) for researching the acceptance and usage of technology (King & He, 2006; Venkatesh & Davis, 2000; Yousafzai et al., 2007). TAM was designed to show how an individual comes to accept and use a technology tool (Mugo et al., 2017). The model has proposed that two factors, perceived usefulness and perceived ease of use, have the most influence on the attitudes and behavioral intentions of an individual when considering the use of a particular technology (Davis, Bagozzi, & Warshaw, 1989). Perceived ease of use has been defined as “the degree to which a person believes that using a particular system would be free of effort” (Davis, 1989, p. 320), and perceived usefulness has been defined as how much an individual believes a tool will increase their ability to perform their job (Davis, 1989). Several research studies have supported the use of TAM for predicting the acceptance and usage of a particular technology (Davis & Venkatesh, 1996; King & He, 2006; Yousafzai et al., 2007).

The purpose of this research study was to collect information about the teaching strategies used with ALEKS in high school mathematics classes and to examine their perceptions of its ease of use and usefulness. The TAM framework was appropriate for this study because this study explored how the perceptions of teachers influence their behaviors by looking at the manner in which they use ALEKS. TAM suggests that a person's attitude influences their behaviors, but that these attitudes are determined by the perceived usefulness and ease of use of a technology tool (Davis et al., 1989). This qualitative research study collected data on these perceptions about ALEKS from high school mathematics teachers and examined how they used the tool in their classes.

Rationale for Methodology

This research followed a qualitative approach because its purpose was to hear the voices of actual mathematics teachers sharing their experiences and perceptions of using ALEKS over the course of a school year. A qualitative approach was appropriate for this study because this study explored the meaning that individuals ascribe to a specific situation and attempts to develop an understanding of their experiences (Creswell & Creswell, 2018; Fossey et al., 2002). Punch (2013) has described qualitative research as an intense contact with a life situation that is reflective of everyday life. This study explored the everyday experience of mathematics teachers using the ALEKS system in their classrooms.

In order to answer the research questions, the voices of high school mathematics teachers who use ALEKS were included; five teachers took part in three interviews with the researcher throughout an academic year. Interviews were chosen as the source of data collection because they help to provide a deeper understanding of the experiences of participants and allow them to give more detailed insights (Fossey et al., 2002). Seidman (2006) has stated that interviews are a powerful way to gain insight into individuals' experiences because they make use of language in order to develop meaning. Qualitative semi-structured interviews can encourage people to share their experiences about sensitive topics where they might otherwise not feel comfortable (Fossey et al., 2002; Ryan, Coughlan, & Cronin, 2007). In this study, teachers may have felt apprehensive about sharing the details of their teaching practices and perceptions, especially if the teachers believed that the practices and perceptions could be viewed negatively. Therefore it was important in this qualitative study to ask open-ended questions in the interviews so that the process was seen more as a conversation than a data-gathering exercise (Knox & Burkard, 2009).

Semi-structured interviews were conducted using an outline of themes, but follow-up questions were also given to the participants (Qu & Dumay, 2011). This study had a list of questions asked of all participants, but it was also flexible and allowed the researcher to probe for more explanation where appropriate (Fossey et al., 2002). A semi-structured format has been considered to be effective when having a conversational interview where participants can share their story in their own language (Qu & Dumay, 2011). This format was also advantageous to the researcher because it provided a way to follow the themes of the research study, helped to build trust (through making the interview seem like a conversation), and still allowed for useful data gathering (Fossey et al., 2002; Knox & Burkard, 2009; Qu & Dumay, 2011).

This study used a multi-interview format so that a trusting relationship between the researcher and participants was able to be built over time (Knox & Burkard, 2009; Qu & Dumay, 2011). A multi-interview approach allowed the researcher to analyze data during the time frame of the research study so that themes could be explored more deeply and so that future interview outlines could be changed (May, 1991). Seidman (2006) has suggested a three-interview format in which each interview serves a different purpose. In the first interview, participants share background information relevant to the research topic. The second interview focuses on the details of their experiences, and the third interview asks participants to reflect on the meaning of those experiences. This study followed a similar format by asking teachers to share their experiences regarding adaptive learning tools in the first interview, asking them to discuss how they have used ALEKS in the second interview, and, finally, asking them to reflect on their perceptions in the third interview.

Assumptions

This study made several assumptions that must be true in order for the research to be reliable. The first assumption was that the teachers in this study were honest and forthcoming when sharing the details of their classroom and use of ALEKS. The procedures put in place to maintain their confidentiality and anonymity were described to participants prior to interviews so that they felt comfortable sharing their experiences and opinions regardless of whether those experiences and opinions were positive or negative. This study also assumed that teachers were being honest about their experiences using

ALEKS and that the tool was indeed being used as the main source of curriculum for their classes.

This research collected qualitative data from teachers who used ALEKS regularly as a part of their core curriculum, and the study assumed that teachers used ALEKS in its full capacity: for assessments, practice, and data tracking. It is also assumed that ALEKS was used throughout the entire school year in the class that they taught. Since the tool mostly operates on a technology device, it is assumed that all of the teachers and students had access to technology capable of operating ALEKS throughout the school day. It also assumed that teachers had some experience or training with using ALEKS.

Definition of Terms

Adaptive Learning Tools are a segment of a digital learning setting in which data and feedback from the learner allow the system to change functions to meet their needs (Bulger, 2016; Gemin et al., 2015).

*Assessment and Learning in Knowledge Spaces (ALEKS) "*is a Web-based, artificially intelligent assessment and learning system" (ALEKS, 2020d).

Computer-based instruction (CBI) is any form of instruction in which a computer is being utilized to provide learning resources, to provide the ability to manipulate representations, or to provide direction to learning processes (Winters et al., 2008).

Intelligent Tutoring Systems are a form of artificial intelligence that mimics a teachers' actions through personalized instruction (Beal et al., 2010).

Personalized learning is characterised by students being able proceed at their own pace, with learning goals that are based on mastery of achieving them (Johnson et al., 2016)

Technology Acceptance Model (TAM) is a model used for predicting how an individual comes to accept and use a technology tool based on its perceived ease of use and its perceived usefulness (Davis, 1989).

Theory of Reasoned Action (TRA) is a model used for predicting the acceptance of a technology that suggests that voluntary behavior stems from a person's beliefs, attitudes, intentions, and subjective norms (Sauro, 2019; Venkatesh & Davis, 1996)

Chapter 1 Summary

The goal of this research study was to understand the teaching strategies used with the ALEKS system and to examine their perceptions of its ease of use and usefulness. A significant amount of literature has addressed the teaching strategies used in mathematics classes (Anthony & Walshaw, 2009; Bartell et al., 2017; Caro et al., 2016; Hattie & Timperley, 2007; NCTM, 2020c; Shute, 2008) and a significant amount of literature has also discussed the role that technology plays in assisting teachers with instruction (De Witte & Rogge, 2014; Hattie, 1999; Ra et al., 2016; Roschelle et al., 2010; Sen & Ay, 2017; Wachira & Keengwe, 2011). Several of the research studies related to adaptive learning tools like ALEKS, however, have investigated only its impact on academic achievement (Karner, 2016; Mills, 2018; Richard, 2019; Sabo et al., 2013; Yilmaz, 2017). Less research has described how ALEKS is used in mathematics classrooms for instruction, and this study helps to fill gaps in the literature by providing qualitative research on the experiences and perceptions of the teachers who use ALEKS. This research provides valuable insights for schools and teachers on how to use ALEKS.

TAM served as the theoretical framework for this study since its purpose is to show how an individual comes to use a technology tool (Davis, 1989). The most influential factors that determine if a person will use a tool or not are its perceived usefulness and its ease of use (Davis et al., 1989; Mugo et al., 2017). In this study, participants were asked to share their experiences using ALEKS and their perceptions of its ease of use and usefulness. According to TAM, these perceptions will impact if and how they use the tool.

This study followed a basic qualitative design in which five high school mathematics teachers were interviewed in a semi-structured format. Interviews were chosen as the source of data collection so that the participants in the study felt comfortable sharing their experiences and so that their perceptions were able to be accurately voiced (Fossey et al., 2002; Ryan et al., 2007). Three interviews took place over the course of an academic year so that the researcher could build a relationship with the participants and so that potential adjustments could be made to the data collection process (Knox & Burkard, 2009; Qu & Dumay, 2011; Seidman; 2006). This study followed a timeline of interviews and data analysis that began in September of 2020 and concluded in May of 2021.

The following chapters include more details of the literature and methodology that were used for this study. Chapter 2 provides background information on the theoretical framework of the study and provides the literature review. The literature review provides what the current research has suggested regarding effective teaching strategies and technology use in high school mathematics classrooms. It also provides information on research studies that have been conducted regarding adaptive learning tools, with a particular focus on ALEKS. Chapter 3 provides a description of the research methodology used for this study. This includes a description of the participants, the data collection procedures, and the data analysis. Chapter 4 describes the results of the coding, data organization, and analysis of the teacher interviews. This chapter presents possible answers to the research questions by breaking down each question into themes. Chapter 5 connects the findings of the study to existing research related to teaching strategies in mathematics classrooms, technology use by teachers, adaptive learning tools, and the TAM framework. It also discusses the implications, limitations, and opportunities for future research.

CHAPTER 2: REVIEW OF THE LITERATURE

The purpose of this study was to understand how high school mathematics teachers used teaching strategies along with the Assessment and Learning in Knowledge Spaces (ALEKS) tool and to measure those teachers' perceptions of its ease of use and usefulness. A literature review was conducted in order to gain an understanding of the topics and concepts related to the components of this study. This literature review includes previous research in the fields of t mathematics instruction, technology integration, and adaptive learning tools. The goal of this review was to determine what the research has suggested as the best practices to use when teaching high school mathematics and then to provide additional literature on how to best integrate technology to enhance those teaching practices. The literature review also provides some research on teaching practices considered to be ineffective and the potential barriers teachers face in technology implementation.

This study focused specifically on the use of one technology tool, ALEKS, a type of adaptive learning system. Therefore, this chapter includes a section devoted to background information on adaptive learning tools, what the research has suggested as its benefits, how it should be implemented, and the perceptions of teachers who have used them. This review also provides details about ALEKS's theoretical foundation, suggestions for its use in conjunction with teaching strategies, and what previous studies have shown about its instructional effectiveness for instruction and effect on achievement. This review summarizes what the current research has shown, identifies the gaps in the literature, and justifies the need for this study.

Theoretical Foundations

The goal of this research was to determine the teaching strategies teachers are using with the ALEKS system and how these teachers perceive its ease of use. The study also asked teachers to give their own viewpoints on how useful the technology tool was for instruction. A significant factor in the level of teachers' use of the ALEKS system is their perception of how easy the tool is to use and of what added benefits it provides. Therefore, the theoretical framework that this study follows comes from the Technology Acceptance Model (TAM).

TAM is based on the Theory of Reasoned Action (TRA), and it is a popular model used for predicting the acceptance of technology use (Venkatesh & Davis, 1996). TRA is a model that suggests that voluntary behavior stems from a person's beliefs, attitudes, intentions, and subjective norms (Sauro, 2019). TAM's intended purpose was to show how a person comes to accept and use a technology tool (Mugo et al., 2017). This model has suggested that two of the most influential factors in an individual's acceptance and use of a particular technology are its perceived ease of use and its perceived usefulness (Davis, 1989). Perceived ease of use refers to the idea that the user would spend less effort using a particular technology than they would by not using it (Mugo et al., 2017). The creator of the model, Davis (1989), has defined perceived usefulness as how much a person believes that using a particular technology will enhance their performance. Davis et al. (1989) stated that the key purpose of the TAM model is to "provide a basis for tracing the impact of external factors on internal beliefs, attitudes, and intentions" (p. 985).

One of the early studies using TAM by Davis (1989) showed a correlation between the use of the model and self-reported use of a technology. In this initial study, participants were asked to predict future use based on their perceptions of usefulness and ease of use. However, although there was a correlation between their use and these factors, no follow up was done to determine actual use. In a later study, Davis et al. (1989) asked 107 MBA students to report their intentions to use a word processor based on perceptions of usefulness and ease of use. This time the researchers followed up on self-reported usage and found a correlation between behavioral intention and use of the word processor (Sauro, 2019). TAM has since become a popular model, and has been widely used and adapted by other researchers (Davis & Venkatesh, 1996; Mugo et al., 2017; Yousafzai et al., 2007).

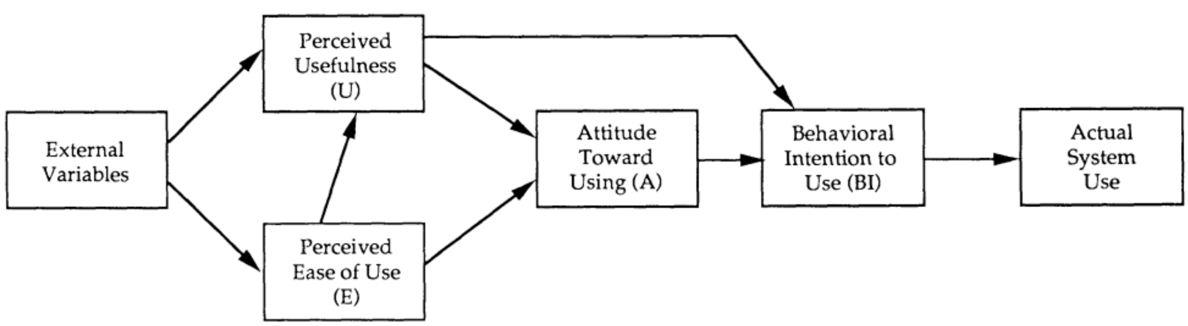


Figure 2.1 TAM

The diagram shown in Figure 2.1 displays the relationship between the factors of perceived ease of use and perceived usefulness and the acceptance of particular technologies (Davis et al., 1989). In this model, perceived usefulness (U) and perceived ease of use (E) are products of external variables such as the design features of a technology tool. Davis et al. (1989) have stated that external variables are features in technology tools aimed at improving U and E. Mugo et al. (2017) have stated that several researchers have argued that internal variables such as the attitudes of the user, pedagogical beliefs, and level of competence with technology can also impact U and E. They have also stated that, within TAM, other external factors could include organizational, technological, and social barriers.

TAM shows that behavioral intention to use (BI) determines the actual use of a system; therefore, it is important to discuss the factors that influence a user's BI. According to Davis et al. (1989), BI is determined by a person's attitude toward using the tool (A) and its perceived usefulness (U): BI = A + U. The relationship between A and BI is that people “form intentions to perform behaviors toward which they have positive affect” (Davis et al., 1989, p. 986). The relationship between U and BI is based on the idea that, within an organizational setting, a person’s behavior will adapt if they feel it will improve their job performance. TAM displays A as determined by both U and E (A = U + E), but adds that U has a direct effect on BI, bypassing A as displayed by the arrows in Figure 2.1.

TAM has been utilized in several research studies that support the relationship between the use of a technology for instruction and its actual implementation (Davis & Venkatesh, 1996). It has been widely used as a way to predict the usage of technologies (Sauro, 2019). Yousafzai et al. (2007) examined 95 studies that were conducted over a 15-year period in a meta-analysis of TAM. Among their conclusions was the observation that both perceived ease of use and perceived usefulness were strongly related to attitudes and behavioral intentions. King and He (2006) performed a meta-study of 88 research studies that directly used TAM. Their findings supported previous research that TAM is a valid model and that perceived usefulness has a strong relationship with behavioral intentions.

Some researchers who have explored TAM in further detail have suggested that other factors outside of the design features of a tool have an impact on teachers' attitudes as well. Mugo et al. (2017) cited organizational barriers, computer self-efficacy, and levels of competence as potential predictors of teachers' attitudes. Venkatesh and Davis (1996) found positive relationships between computer self-efficacy and perceived usefulness/ease of use, supporting the idea that TAM can be extended to other external factors. TAM has been adapted into several different models since its inception (Mugo et al., 2017), and its creator has even adapted his model into the TAM 2. In this model, Venkatesh and Davis (2000) used a more specific list to describe the factors that influence U and E: (1) experience, (2) subjective norm, (3) image, (4) job relevance, (5) output quality, (6) result demonstrability. However, for the purposes of this study, only the original TAM is used and described.

The TAM framework served as the model for this study to follow. This model was appropriate for this qualitative study because TAM focuses on how the perceived usefulness and ease of use of a technology tool influence the behavior of an individual considering the use of such a tool (Davis, 1989). This study measured teachers' perceptions of the ease of use and usefulness of ALEKS over the course of an academic semester. This study also asked teachers how they used ALEKS in their classrooms for instruction, assessment, and data analysis. Based on their perceptions of the ease of use and usefulness of ALEKS, teachers form their attitudes toward use of the tool which will impact their use of the technology. This study analyzed how teachers use ALEKS for teaching mathematics.

Literature Review

This literature review provides support for this study by synthesizing the current research on teaching mathematics, on the role of technology in teaching mathematics, and on what has been studied in the field of adaptive learning tools. This review begins with an overview of effective high school mathematics classroom strategies and the research-based teaching techniques that correlate with student success. The following section discusses the role technology plays in classroom instruction and the evidence supporting its use. Another section of this review is devoted to the history of adaptive learning tools, to the different types of programs that are commonly used, and to what the research describes as their benefits and limitations. Since this study focused on the ALEKS system, the final sections provide a description of how the tool functions, its theoretical background, and what research has been conducted related to its use.

Effective Teaching Strategies in High School Mathematics

The success of a student in a mathematics classroom is influenced by several internal and external factors. Many of these factors may be out of the control of the instructor, but there are numerous instructional strategies a teacher can implement that can contribute to academic success (Arends, Winnaar, & Mosimege, 2017). There has been considerable research that supports the positive impact that effective teaching strategies have on student learning. Caro, Lenkeit, and Kyriakides (2016) cited a 2012 student questionnaire introduced by the Programme for International Student Assessment (PISA) that described the instructional practices of mathematics teachers with regard to classroom management, student-oriented instruction, and cognitive activation strategies. The results of this study indicated that the instructional practices of teachers are the most significant factor that affects the academic performance and the development of metacognitive skills among students (Caro et al., 2016). One of the most well-referenced sources of evidence for the effectiveness of teaching strategies came from Hattie (2012), who reviewed over 800 metastudies that collectively included millions of students. In the meta-analyses, the most influential factors affecting student learning were student self-regulation behaviors, feedback, teacher-student relationships, and teaching strategies that involve questioning techniques and problem solving (Arends et al., 2017; Hattie, 2012). Although there are many variables that influence the failure or success of mathematics students, a significant body of evidence has suggested the importance of quality teaching practices.

Effective Teaching Strategies

Teachers learn about effective teaching practices by seeking out the research that has been made available through several organizations. The National Council of Teachers of Mathematics (NCTM) is an organization that provides several resources for math teachers. They are one such organization that has attempted to organize research on effective teaching strategies into standards for math teachers to follow. NCTM (2020a) listed eight research-based standards that they recommend teachers follow:

1. Establish mathematics goals to focus learning.
2. Implement tasks that promote reasoning and problem solving.
3. Use and connect mathematical representations.
4. Facilitate meaningful mathematical discourse.

5. Pose purposeful questions.
6. Build procedural fluency from conceptual understanding.
7. Support productive struggle in learning mathematics.
8. Elicit and use evidence of student thinking.

According to the NCTM (2020a), these standards are research-based and consistent with what other researchers have found to be effective. These standards have suggested using previous evidence of student learning to adjust instruction and aligning learning goals with a student's own progression of understanding (NCTM, 2020c). Bartell et al. (2017) collected research on equitable practices for teaching mathematics and cited the importance of first recognizing where a student is developmentally and then building from their current understanding. Aligning learning goals in this way also helps students to make connections across mathematical ideas, concepts, and procedures (NCTM, 2020c). Effective teaching, in this regard, comes down to the instructor providing manageable academic outcomes for each student. Without at least having an understanding of where a student is in his or her learning progression, a teacher is not able to set a reasonable path toward improved student understanding.

In terms of actual instruction, the NCTM (2020c) has recommended an approach that focuses on mathematical reasoning and problem-solving. Teachers can accomplish this by facilitating opportunities for analyzing mathematical approaches, by emphasizing reasoning and sense-making, and by using purposeful questioning techniques (Caro et al., 2016; NCTM, 2020c). NCTM (2020c) has defined reasoning and sense-making as connecting previous knowledge to a current situation in a way that allows students to think about and apply mathematics in meaningful ways. This is effective because it allows for original thinking about ways to do mathematics (Anthony & Walshaw, 2009). Other recommended strategies that have shown evidence of success include: (1) fluency with procedures, (2) providing challenges, and (3) applying both student-centered and teacher-directed approaches (Anthony & Walshaw, 2009, Caro et al., 2016, NCTM, 2020b). Student-oriented approaches are beneficial because they allow for differentiation, promote student engagement in mathematical explanations, and build reasoning skills (Caro et al., 2016).

There are many approaches teachers can take in a high school setting to meet the needs of students. The strategies most commonly used by high school math teachers are: (1) repetitive exercises, (2) deductive reasoning, (3) inductive approaches, (4) cooperative learning, and (5) classroom lecture (Cardino & Cruz, 2020). While all of these methods have shown evidence of being effective, there are more specific classroom tactics that can be used in math classrooms. For example, teachers can encourage the use of multiple representations and model processes of mathematical explanation using oral, written, and concrete communication (Anthony & Walshaw, 2009). Communication is a valuable component of an engaging classroom, and one that both the teacher and the students need to take an active role in. Discussion involves students describing and justifying their mathematical procedures, solutions, and ideas (Arends et al., 2017). This requires students to use higher-order thinking skills which are believed to have a positive effect on learning (Wenglinsky, 2002). However, all students may not be ready to engage in such activities, and it is up to the teacher to provide opportunities for some students to model the behavior and therefore push all students to develop these higher-order thinking skills.

Another strategy that affects student success is the formation of positive teacher-student and student-student relationships. These positive relationships can be achieved by establishing clear expectations or norms, applying effective classroom control strategies, and by maximizing learning opportunities (Anthony & Walshaw, 2009; Bartell et al., 2017, Caro et al., 2016). The analysis Arends et al. (2017) conducted of six measures of mathematics classroom practices suggest that positive interactions between teachers and students and amongst learners are significant factors that affect student performance. Communicating to students the expectations for their behavior and communicating the policies and procedures of the classroom are also contributing factors to student success (Bartell et al., 2017).

Assessment & Feedback

Assessment and feedback are among the most important aspects of teaching because they have the strongest influence on learning (Havnes et al., 2012). Specifically, one of the most important practices for teachers to utilize is assessment of learning, also known as formative assessment. In this process, teachers provide students with learning activities, collect feedback, and then make adjustments in response to student needs (Anthony & Walshaw, 2009; Arends et al., 2017; NCTM, 2020b). Many researchers have shown that feedback can be used to modify a student's thinking or behavior and to help them improve their learning (Hattie & Timperley, 2007; Shute, 2008). Shute (2008) has identified feedback as a valuable tool because it can reduce uncertainty about a topic, lower a student’s cognitive load, and correct misconceptions about a learning task. There has been research conducted on the ways formative assessment can be used by teachers and on its relative effectiveness. Barry (2008) referenced a meta-study conducted by

Mid-Continent Research for Education and Learning (McREL) in which nine instructional strategies were identified as enhancing achievement for all students of any subject or grade level. The study indicated that providing feedback was one of the most effective strategies.

Other well-known researchers in the field of education have also studied feedback, have promoted its use, and have drawn conclusions about the most efficient ways to use it. Hattie (1999) synthesized over 500 meta-analyses of various aspects of learning, data that represented over 20 million students. He determined that feedback related to how to accomplish a learning task was the most effective, whereas feedback that used praise, rewards, or punishment was the least effective.

Marzano, Pickering, and Pollock (2001) believed that feedback needs to be timely, specific and include explanations. They cited their research which shows its significance in student achievement. Schute (2008) cited a 2001 study by Corbett and Anderson investigating learning mathematics with a computer-based tutoring system. The latter study explored four feedback conditions to find the most effective procedure for enhancing learning. As previous researchers found, feedback that was timely and provided information on the task was the most effective (Corbett & Anderson, 2001). The most thorough research studies have pointed to specificity and timeliness as the most influential factors in feedback that improves student learning.

Summary of Effective Teaching Strategies in Mathematics

This section has described the many ways in which a teacher can implement strategies to enhance learning in a mathematics classroom. What the research has suggested is that teachers who establish a classroom environment that allows students to engage in meaningful activities that focus on reasoning and problem solving are the most effective (Anthony & Walshaw, 2009; Caro et al., 2016; NCTM, 2020a). Teachers create such environments by fostering positive behaviors through the use of classroom management and feedback techniques (Arends et al., 2017; Bartell et al., 2017; Hattie, 1999; Hattie & Timperley, 2007; Havnes et al., 2012; Shute, 2008). One way to potentially enhance the ability of a teacher to engage their students in more meaningful learning activities is through the use of technology.

Technology Use in Mathematics Classrooms

A vast amount of evidence has supported the idea that the use of instructional technology in high school classrooms improves student outcomes (Li & Ma, 2010; Murphy, 2016). However, these positive outcomes are only realized if they are properly supported by school administrators and correctly implemented by teachers (Goos & Bennison, 2008; Karatas et al., 2017; Pierce & Ball, 2009; Wachira & Keengwe, 2011). Implementing technology in a way that improves achievement often comes down to the beliefs of the teacher (Ertmer et al., 2012). Since teachers are the ones in control of the use of the technology, they play a critical role in making sure the tools are used effectively (Anthony & Walshaw, 2009). Teachers must integrate technology as a means of enhancing teaching practices that are already effective. For instance, Li and Ma (2010) concluded in their meta-analysis of technology use in high school mathematics classrooms that a constructivist approach to computer use was most effective at promoting academic achievement.

Benefits of Teaching with Technology

There are many benefits of using technology that are specific to the learning of mathematics, and there has been plenty of support for its use in the literature. Murphy (2016), in his literature review of technology implementation in high schools, has described its numerous benefits: (1) increased student engagement and motivation, (2) better teacher-student interaction and student collaboration, (3) greater accuracy of mathematical computation, (4) greater student comfort with learning mathematics. Li and Ma (2010) conducted a meta-study of 46 studies and over 36,000 participants, and were able to indicate statistically significant positive effects of computer technology on mathematics achievement.

Sophisticated calculators, computer devices, software or cloud-based programs, data analysis tools, and many others are technologies specific to learning mathematics (Sen & Ay, 2017; Wachira & Keengwe, 2011), and these tools could provide teachers and students with ways to explore mathematics at a deeper and more meaningful level (Demana & Waits, 2000; Cheung & Lavin, 2013; Longnecker, 2013; Murphy, 2016). Technology tools in mathematics classrooms may also provide simulations, multiple representations of visualizations, and modeling that help learners engage in complex thinking skills (Murphy, 2016; Sen & Ay, 2017), and with these technologies, students and teachers are able to extend the range and quality of mathematical ideas to provide more meaningful and realistic problems for students to solve (Wachira & Keengwe, 2011). Recent advancements in technology have allowed for more efficient and more accurate forms of common mathematical concepts related to calculation, data collection, analysis, and graphing (Wachira & Keengwe, 2011).

The capabilities of these mathematical tools allow teachers to utilize more research-based teaching strategies like: (1) developing creativity, (2) developing higher order thinking skills, (3) promoting student reasoning, and (4) improving problem-solving (Sen & Ay, 2017). The NCTM (2020a) teachers guide has suggested that technology can improve the reasoning and sense-making of students by reducing the workload of performing mathematics so that students can focus on thinking about problem-solving strategies and multiple representations. DeWitte and Rogge (2014) have identified specific skills that students can develop when using technology: (1) developing problem-solving skills, (2) challenging their peers' thinking and understanding, and (3) using tools to visualize misconceptions. Further evidence has supported the idea that using technology to help build conceptual understanding and problem-solving skills can make complex problems easier to understand, allow for multiple perspectives to be shown, and can even improve attitudes towards learning mathematics (Bray & Tangney, 2017; Pilli, 2008; Smeets, 2005). These positive effects of using technology come from the ability of technology to provide more efficient and accurate calculations and data collection procedures as well as simpler (and more detailed) graphing, and modeling techniques (Wachira & Keengwe, 2011). These benefits help to create effective mathematics instruction; however, they are most often realized when teachers implement these tools properly.

Teaching Methods with Technology

The ways in which teachers implement technologies in their classroom play a significant role in how the technologies are utilized and how effective they are. Since the teacher often controls when and how technologies are utilized, their decisions are the most important for successful implementation (McCulloch et al., 2018). Researchers have explored the idea of teaching styles impacting technology integration in classrooms. Bray and Tangney (2017) cited multiple meta-analyses showing a connection between a constructivist teaching philosophy, higher levels of integration, and improvements in the mathematical understanding of students. Rakes, Fields and Cox (2006) have stated that constructivist learning environments frequently utilize communication and visualization technology that enhances the ability of students to reason and problem-solve. The literature has further suggested that, in order to truly realize the benefits of technology, a teacher needs to use a less traditional approach toward teaching and be more of a facilitator of information (Bray & Tangney, 2017; Levin & Wadmany, 2006; Monaghan, 2004). A teacher as a facilitator provides structure, tracks progress, and creates problem solving opportunities for students (Bray & Tangney, 2017; Kynigos, 2019).

Teachers who implement a constructivist approach to teaching may be more likely to utilize technology regularly than those who take a traditional approach (Gilakjani, Lai-Mei, & Ismail, 2013; Levin & Wadmany, 2006). Levin and Wadmany (2006) have said that this is because teachers' beliefs about technology use influence the decisions they make with technology. Teachers who use a traditional approach may favor a more rigid pedagogy when they control the curriculum. Teachers who do not use the technology for problem-solving and reasoning often use it in less effective ways (McCulloch et al., 2018). For example, using technology for mostly drill and practice activities has been shown to make a negligible impact on student achievement (McCulloch et al., 2018). As with other teaching strategies, technology is often used in ineffective ways. Kynigos (2019) cited several ways in which technology is utilized ineffectively: (1) using only a single tool, (2) applying a tool with one approach and assessing using another, (3) using a technology without considering the pedagogy for which it was designed, and (4) making assumptions that simply using the tool will lead to an improvement in learning. When a teacher decides to make use of a technology tool, he or she needs to consider how it functions and how it can be best utilized to support teaching practices, not simply rely on the tool exclusively. For instance, teachers taking a constructivist approach with technology are more likely to use technology effectively (Bray & Tangney, 2017; McCulloch et al., 2018; Rakes et al., 2006).

Feedback with Technology

In terms of teaching practices, quality feedback has been considered one of the most effective ways to improve student achievement (Barry, 2008; Hattie, 1999; Havnes et al., 2012). Technology advances have made feedback more immediate, personalized, and detailed (De Witte & Rogge, 2014; Ra et al., 2016). Research has also suggested that the benefits of computer-generated feedback are effective for student learning (Hattie, 1999; Roschelle et al., 2010). Shute (2008) cited meta-analysis studies related to the impact of feedback from computer-based instruction, and in the 22 studies that were analyzed, it was determined that immediate feedback was more beneficial than delayed feedback.

Other studies have also attempted to investigate the impact of computer-generated feedback in mathematics classrooms. Attali and van der Kleij (2017) explored multiple mathematics classrooms using three different types of computer-based feedback on a practice test: (1) providing knowledge of correct response and more feedback right away, (2) giving immediate feedback of a correct response and then more detailed feedback upon completion, and (3) changing the question format to multiple choice and providing the correct answer. Their study asked students to take a post-test which was a second version of the practice test. The analysis of the test scores from the 2,445 participants revealed that immediate feedback with more detailed feedback upon completion (when given in the pre-test) resulted in a higher performance on the post-test. Corbett & Anderson (2001) explored feedback timing and control in a cognitive-tutoring system in which students were placed into three groups: (1) immediate feedback and error correction, (2) immediate error flagging and student correction, and (3) feedback on demand with student correction. Their results showed that the group with immediate feedback and error correction was the most efficient. Several sources have provided research supporting feedback that is timely and specific, and adaptive learning technologies have the capability to deliver it to students (Corbett & Anderson, 2001; Marzano et al., 2001; Schute, 2008).

Implementation Barriers

As stated before, the use of technology could enhance teaching practices, but there are multiple factors that can affect the use of that technology. These factors include the teachers' confidence in using the technology, teachers' beliefs about how easy it is to use, and teachers' willingness to change their teaching practices (Karatas et al., 2017; Kopcha, 2012; Pierce & Ball, 2009; Wachira & Keengwe, 2011). Ertmer et al. (2012) have stated that teachers' own beliefs and attitudes towards technology are one of the most influential factors influencing student success and that these beliefs and attitudes can even overcome any technological or administrative barriers.

There are several internal and external barriers that prevent utilizing instructional technologies at their full capacity. Some of the external barriers are educational policies, lack of access to resources, and lack of support from administration (Goos & Bennison, 2008). Studies have also identified a lack of the right type of technology, poor training, and ineffective professional development as factors deterring technology integration (Wachira & Keengwe, 2011). Rogers (2000) cited qualitative research from teachers citing availability and access of resources, technical support, staff development as external barriers. Several studies have stated that a lack of time to learn how to use technology tools is one of the most significant barriers because teachers are unlikely to use a tool they are uncomfortable with (Wachira & Keengwe, 2011; Kopcha, 2012; Rogers, 2000).

Internal barriers stem from negative attitudes of teachers towards the use of technology and a lack of confidence in its use (Kopcha, 2012; Pierce & Ball, 2009; Wachira & Keengwe, 2011). Pierce and Ball (2009) found support for this in their own study of 92 high school math teachers who were surveyed about their perceptions of technology use. Their findings reported an overall positive attitude towards technology but found that teachers' perceptions of the ease of use and usefulness of the tools created a barrier. The teachers needed to be convinced that it would improve student performance before they would accept it. This is consistent with other research studies about the need for professional development and training for teachers (Goos & Bennison, 2008; Kopcha, 2012). In his review of the literature of teacher perceptions as barriers towards technology use, Kopcha (2012) listed teachers' beliefs about the "usefulness of and difficulty associated with integrating technology influencing whether they use technology for instruction" (p. 1009).

Summary of Technology Uses in Mathematics

The literature synthesized in this section provides a body of evidence supporting the use of technology in mathematics classrooms. These tools allow teachers and students to explore mathematics more deeply by simplifying calculations, enhancing graphing capabilities, allowing for more thorough data collection and analysis, and improving model generation (Murphy, 2016; Sen & Ay, 2017). These common mathematics practices benefit students by allowing them to engage with more problem-solving and reasoning activities, activities which have been identified in the literature as helpful in building mathematical understanding (Caro et al., 2016; NCTM, 2020c). Technology can also enhance the feedback given to students by making it more personalized, immediate, and specific (De Witte & Rogge, 2014; Ra et al., 2016). However, a teacher plays a significant role in ensuring that the technology is implemented regularly and, in a manner, necessary for these benefits to take place. Teachers who are more confident (and who believe that the technology is useful for students) are more likely to use it and take on the approach of a facilitator. This role of a facilitator follows a constructivist viewpoint of learning which has been shown to be more student-centered and beneficial for students (Bray & Tangney, 2017; Levin & Wadmany, 2006). Recently developed technologies, like adaptive learning tools, are able to further enhance the capabilities of instruction and feedback for mathematics teachers. It is critical for the success of teachers and their students that teachers understand how these tools function and the best ways to implement them.

Adaptive Learning Tools

Adaptive learning systems have become increasingly popular among high school teachers as cloud-based technologies and personalized learning tools have been further developed. There are several levels and types of adaptive learning tools, and many provide both instruction and feedback for students using algorithms that are based on student behavior patterns. Teachers can use these programs to track student progress, analyze classroom data, and provide personalized instruction based on student needs. This section summarizes what these tools are and what their histories are, and describes the research into some of the most well-known tools that are used in mathematics classrooms.

Definition

Adaptive learning tools are one piece of a digital learning setting in which data and feedback from the learner allow the system to change its functions to meet their needs (Bulger, 2016; Gemin et al., 2015). For the purposes of this review, digital learning settings will be defined as an instructional practice that uses technology to enhance the learning experience of a student (Gemin et al., 2015). Cognitive tutoring systems, programs that utilize machine learning, and e-learning platforms are all adaptive learning tools used in digital learning settings. As users interact with adaptive learning tools, the content and workflow adapt to provide learning content that fits the needs of the user (Bulger, 2016; Hsieh, Lee, & Su, 2013; Murray & Pérez, 2015). This content can enhance the learning experience by adapting instruction, curriculum, or the actual learning path so that the student will have a more efficient learning experience (Hsieh et al., 2013; Murray & Pérez, 2015). The instruction can vary between students based on their responses to assessment questions. The adaptive software tool might provide a struggling student with remedial practice while a student displaying mastery of the topic would be provided with more challenging work. Although a teacher could provide a similar path for the student, the idea of adaptive learning tools is that they can assess and automatically provide instruction for the student.

Some advanced systems are developed with different capabilities. As these programs become more sophisticated, they can also accommodate different student motivations and pace (Oxman, Wong, & Innovations, 2014). Some systems are capable of modifying the presentation of content based on the preferences of the learner (Murray & Pérez, 2015). One example of this would be a student watching an instructional video instead of reading about a topic, a decision based on data collected about the user's preference. Other programs can be personalized to speed up or slow down the level of instruction based on student needs. For example, some students might begin with higher-level problems than others or may require fewer questions be answered before advancing. There are also effective systems which are being developed to monitor students' facial expressions in order to collect information about boredom or frustration (Means et al., 2013). These affective systems factor in the student's emotional state by monitoring input levels of arousal, posture, and skin sensors to adapt instruction (Oxman et al., 2014). This type of tool, however, has yet to make it into mainstream use.

There are several types of adaptive learning systems. A rule-based system functions in an if-then format in which input from the user drives the decision making of the program (Oxman et al., 2014). In this system, a student might receive a hint, repetition of content, or a new explanation if the system so decides. Math Space and IXL are examples of rule-based systems that follow this approach (Hollands & Pan, 2018; IXL, 2020; Math Space, 2020). Another type of adaptive learning technology is an algorithm-based system. This is more sophisticated software that uses functions to analyze the performance of a student over a longer period of time and is able to use the collected data to learn about the student (Oxman et al., 2014). An algorithm-based system essentially collects the historical data of a student's learning and uses it to make decisions about instruction in the future. Khan Academy and ALEKS are examples of algorithm-based systems in which a user's past performance contributes to the analysis of a students' needs (ALEKS, 2020a; Barrett, 2018; Khan Academy, 2020). Programs like ALEKS provide students with opportunities to show work in their problem solving so that the system can assess learning needs by looking at their responses, number of attempts, and time needed (Roberts-Mahoney et al., 2016; Yilmaz, 2017). Many programs feature components of both rule-based and algorithm-based systems.

History

The history of adaptive learning systems began with the first use of computer-based instruction. Most researchers have pointed to the PLATO project at the University of Illinois in the 1960s as one of the first attempts to deliver instruction using digital technology (Gemin et al., 2015). The PLATO project was considered to be the first computer assisted instruction system allowing for coursework to be done with communication tools, graphics, and feedback (Jones & Latzko-Toth, 2017). PLATO was in use for multiple decades, and many of its tools served as precursors to online message boards and chat rooms. The earliest forms of computer-based instruction were essentially classified as "drill and kill" programs that utilized questions to collect information on procedural knowledge (Hannafin & Foshay, 2008). Early uses of adaptive learning tools in schools were for credit recovery where students could use computers with little interaction with a teacher (Gemin et al., 2015). As schools began to use computer-based instruction more frequently, cognitive tutoring and assessment programs started utilizing more artificial intelligence (Yilmaz, 2017).

An increased emphasis on personalized learning has also played a role in the progression of adaptive learning. Suppliers and universities began to take note and started partnering with adaptive learning systems to create programs like ALEKS and Pearson MyLab (Zimmer, 2014). Adaptive learning tools like Khan Academy, ALEKS, and IXL are now commonly found in K-12 school districts (Gemin et al., 2015). Some researchers believe that the use of strictly adaptive learning for online education will soon become a normal aspect of schooling (Oxman et al., 2014).

Classroom Uses

The rationale for the use of adaptive content is that each student is unique in terms of their abilities, backgrounds, and motivations. Having only one path for students to succeed does not address differences among students. Shute and Zapata-Rivera (2012) provided three reasons for adapting content for students: (1) differences with incoming knowledge, (2) a variety of relevant abilities and disabilities, and (3) demographic/socioeconomic differences. Authors stated that failing to adapt content can affect learning due to boredom, frustration, and lack of confidence. The capabilities of adaptive learning programs can help enhance student learning by providing immediate feedback, learning mastery, and data collection (Smith, 2018). Studies have shown evidence that the use of adaptive learning tools enhances student performance in math classrooms (Bochniak, 2014; Cheung & Slavin, 2013). Bochniak (2014) used a quasi-experimental design with two groups of sixth-graders learning math fluency facts, one group using an adaptive learning tool, the other using traditional approaches. The students used the last ten minutes of class every day for a three-week period to practice their math fluency in their groups. The group using the adaptive learning tool performed better, in a statistically significant way, on a post test than the traditional group. Smith (2018) cited several studies displaying evidence of positive student attitudes toward the use of adaptive learning tools.

There has been limited research into how adaptive learning tools are implemented in traditional classrooms. It is important for teachers to buy into the technology since they often control when, how, and why students have access to the tools (Bebell & O'Dwyer, 2010). This is also critical because, when properly implemented, computer-based learning can lead to learners being more engaged and displaying higher levels of understanding (Longnecker, 2013). Poorly implemented adaptive learning systems, however, could actually lead to negative results. For instance, Baker (2010) studied computer-based learning environments and found that boredom and confusion were commonly occuring deterrents towards learning. He suggested that effort should be put into combating these student feelings through interventions. Some recent research has suggested that learning complex topics with adaptive learning tools can be challenging due to lack of scaffolding (Azevedo et al., 2005). Liu (2017) also suggested the importance of planning and designing when implementing adaptive learning tools. He used a mixed methods design among first-year college students, using adaptive learning tools to evaluate their learning. Although the study showed favorable experiences for the students, he acknowledged that a lack of design in the implementation of the tools might have limited the success.

Examples of Adaptive Learning Tools

As adaptive learning systems have become more prevalent in both K-12 and higher education, it is important to review the evidence pertaining to the learning that occurs with such tools. This section reviews adaptive learning tools in both a broad and narrow sense. It also reviews specific adaptive learning tools that are commonly used in learning environments in both K-12 and higher education. Studies that involve higher education are included in this review due to the prevalence of adaptive learning tools in those environments and the amount of research that is available to review. Since these tools are used in both online and traditional learning environments, the use of the tools in both types is explored.

Computer Based Instruction

Since adaptive learning most often occurs through the use of educational technology, a review of the research related to computer-based instruction is an important place to start. Computer-based instruction (CBI) is any form of instruction in which a computer is utilized to provide learning resources, provide the ability to manipulate representations, or provide direction to learning processes (Winters et al., 2008). The features of CBI are similar to those that constitute an adaptive learning tool in that they provide resources and direction to the user. Although CBI can be considered an umbrella term encompassing many forms of instructional technology, adaptive learning tools are considered to be an example of CBI. Therefore, exploring the research relating to CBI is helpful in gaining an understanding of the effects of adaptive learning tools.

There has been a significant amount of research related to CBI and its value to learning. Longnecker (2013) cited a review of over 200 studies of CBI in K-12 classrooms over the past decade that show support for improved test scores, attitudes, and self-efficacy. Burns, Kanive, and DeGrande (2012) explored math interventions with 216 elementary students who were practicing math facts. The students in the study receiving the intervention used a computer program to practice their math skills three to five times per week whereas the control group used the same tool less than once per week. Their results indicated significant gains by the study group compared to the control group, suggesting that CBI is an effective tool for intervention. Cheung and Lavin (2013) have investigated the use of many different types of educational technologies and found CBI to have one of the most significant impacts on mathematical achievement. In a large meta-analysis involving over 36,000 students, Li and Ma (2010) found positive effects on student achievement from the use of CBI in mathematics instruction. They suggested that CBI was more effective when used from a constructivist point of view.

However, not every study related to CBI has shown positive results. Bochniak (2014), in his meta-analysis of 38 studies, found CBI to be most beneficial when used as a supplement, but his results were less significant than those in the previously cited literature. Campuzano et al. (2009) found mixed results when exploring different software tools for reading and math. In some cases, students showed significant effects, especially when using the products over an extended period. However, many of the software products used for CBI showed statistically insignificant results. For many schools, CBI has been used for practice in preparation for testing. The research of using CBI for the purposes of improving test scores has been positive (De Witte, Haelermans,

& Rogge, 2015; Hannafin & Foshay, 2008; Yilmaz, 2017). However, Yilmaz (2017) countered in his review of studies of adaptive learning that, although the research suggests CBI use is correlated to improvements in test scores, many of the studies have design flaws that may have skewed the results.

Khan Academy

Khan Academy is an international online platform that provides videos, activities, and adaptive learning resources for free. Khan Academy is a form of computer-based instruction that offers online tutoring with a mastery-based learning approach (Barrett, 2018). Although the program can be used by anyone, it has often been used as a resource for traditional and online schools (Light & Pierson, 2014).

There have been some research studies that connect the use of Khan Academy to academic achievement. Barrett (2018) conducted a study of high school students who used Khan Academy as their primary resource for Algebra 1, Geometry, and Algebra II over a six-week period. The results of the study indicated that both the treatment and control group received positive outcomes. This study randomly assigned students to a treatment group that received personalized learning targets on Khan Academy based on a pre-test. The control group used Khan Academy as a standard course of study. Barrett (2018) acknowledged a small sample size of only 44 students might have contributed to the lack of a difference in post-test scores between the two groups.

Chu et al. (2018) also found an improvement in student achievement - as measured by the Northwest Evaluation Association (NWEA) MAP scores - when utilizing Khan Academy with 103 grade-school students in California. This study also followed an experimental design in which students in the treatment group received lessons from Khan Academy while the control group did not. The treatment group was encouraged to use Khan Academy resources twice a week for four weeks while the control group only had access to Khan Academy and was not given instructions for its use. The results of the study showed a statistically significant improvement of 16% on the MAP test for those students who completed the Khan Academy lessons compared to a 10% improvement from the control group. A study of Khan Academy in a blended-learning environment showed evidence that using the tool in a flipped classroom led to increased student achievement and enhanced understanding measured by an achievement test and student questionnaire (Zengin, 2017).

Kelly and Rutherford (2017) used a quasi-experimental design for a study with a group of 39 seventh-grade students who used Khan Academy as an intervention over a four-week period. They asked students in the experimental group to use the tool independently for a minimum of 30 minutes per day while the control group of 36 students were not encouraged to use Khan Academy. The teacher tracked their participation minutes, hypothesizing that students who used the tools for more time would see higher math test scores. The results of the study showed no significant difference between the control group and the experimental group, nor was there a significant difference in scores based on the amount of time spent using the tool.

A larger quasi-experimental study of 131 ninth-grade students attempted to determine if using Khan Academy for fifteen minutes per day would have a significant effect on an end-of-the-year standardized test (Kelly, 2018). The pre-test and post-test were both the North Carolina READY Math I assessment, and students took this test in October and again in May. The experimental group used Khan Academy every day with grade-level instruction while the control group just received the instruction without Khan Academy. Kelly (2018) found no significant difference in the post-test scores of the students.

There have been several studies that have explored other facets of Khan Academy in terms of the perceptions of teachers and students. Light and Pierson (2014) studied how five teachers in Chile used the tool in their classrooms. Their findings indicated that when all of the teachers had the students use the tool independently, it had an impact on how the teachers interacted with students. Light and Pierson (2014) observed, through analyzing responses from teachers on a questionnaire, an increased level of engagement from students and an improvement in the use of teaching strategies. Zengin (2017) explored the use of Khan Academy in a flipped classroom model. The students in this study used Khan Academy to watch videos at home prior to coming to class. The 28 college-level students in this study showed improvement in their learning of a mathematical topic (as measured by a post-test) and offered more positive feedback on a questionnaire that asked how Khan Academy increased in their understanding. These two studies attempted to make connections, based on the perceptions of students and teachers, between how Khan Academy is used in instruction and levels of success achieved; however, these studies had a small sample size and failed to measure results against a control group.

The research specifically related to Khan Academy has shown mixed results in terms of academic achievement related to test scores. These studies have primarily focused on students using Khan Academy independently with some teacher support, but they have not provided details nor did they try to analyze the role of the teacher in using

Khan Academy as a learning tool. Studies from Light and Pierson (2014) and Zengin (2017) attempted to collect information on the perceptions of students and teachers, but did not provide insight into the ways in which teaching strategies were used.

Intelligent Tutoring

Research has shown evidence that intelligent tutoring systems, a form of adaptive learning software, support learning in many types of settings. An intelligent tutoring system is a form of artificial intelligence that mimics a teacher's actions through personalizing instruction (Beal et al., 2010). Baker et al. (2010) have described these tutoring systems as valuable tools for promoting active learning and have shown that these systems are an improvement when compared to inexperienced tutors. Kulik and Fletcher (2016) described a meta-analysis of 50 evaluations of intelligent tutoring systems. Although the evaluations were heavily dependent on the type of assessment tool used and were limited on the alignment of objectives, they concluded that intelligent tutoring systems "typically raise student performance well beyond the level of conventional classes" (p. 70).

VanLehn's (2011) research also explored the impact of intelligent tutoring on academic achievement through multiple experiments that reviewed the effectiveness of three types of tutoring: human interaction, computer-based, and no tutoring at all. The computer-based tutoring consisted of multiple styles that provided step-by-step guidance to users, the human-interaction tutoring was considered to be tutoring with a person, and the no tutoring was just instruction without tutoring. He was able to conclude in his review of the experiments that the effect size of the intelligent tutoring system was nearly the same as that of the human tutors.

Kulik and Fletcher (2016) also found no difference when comparing an intelligent tutoring system to the traditional instruction used in 27 evaluations of Algebra I classrooms. Although they concluded that the system contributed to raised test scores, the results were not significant enough to conclude that there was much difference between the use of the system and traditional instruction. Campuzano et al. (2009) performed a comparison study between two Algebra I classes in which one utilized an intelligent tutoring software while the other used non-intelligent tutoring tools. This study, conducted over a six-week period, revealed no significant differences between the two groups. This was consistent with other research conducted by Campuzano et al. (2009) where the type of intelligent tutoring tool did not have a significant impact on student achievement. Although intelligent tutoring systems have seemed to compare somewhat favourably to human interaction, there has not been much evidence to suggest that they represent a significant improvement over other adaptive learning tools. It is important to note that these studies could be classified as a media comparison since the instructional practices in the studies have been the same and only the medium has changed (Clark, 1994).

Other Adaptive Learning Tools

This first section investigates studies with different types of adaptive learning systems in higher education. Foshee, Elliot, and Atkinson (2016) have referred to technology-enhanced learning (TEL) as software programs that are adaptive, self-paced, and individualized. They investigated the use of TEL in their study of the beliefs of 2,880 college remediation students concerning their academic ability and behaviors. Their results suggested that the TEL tools had a positive effect on student learning and completion rates. Griff and Matter (2013) assessed the adaptive learning tool LearnSmart in college-level anatomy and physiology courses. They concluded - using pretests, posttests, and grades as assessment measures - that there was no significant difference in academic achievement between students using the tool and those not using it. Griff and Matter (2013) speculated that proper alignment between adaptive learning tools and assessments may contribute to more significant learning gains.

There have been a few studies that have attempted to measure the effect of adaptive learning outside of academic achievement. Sun, Xie, and Anderman (2018) explored equation modeling in college-level Calculus classes that featured elements of adaptive learning. The study showed positive results in student learning and in self-efficacy. Murray and Pérez (2015) compared the instructional methods in a digital literacy course in an online setting. One group was placed in an adaptive-learning setting while the other used a traditional approach with quizzes derived from the textbook. Again, no significant differences in learning gains were found, but there was evidence that the adaptive learning system influenced the students' persistence and engagement.

Research on a variety of adaptive learning tools used in K-12 schools has shown mixed results. Haelermans and Ghysels (2013) used a randomized field experiment to assess the effects of an online practice tool on the mathematics skills of seventh grade students. They were able to find a positive relationship between the amount of time using the online practice tool per week and the student's performance in math class. Two popular adaptive learning tools in K-12 classrooms are IXL and eSpark. IXL is an online tool used by over six million people that features practice and feedback on several K-12 subjects (Hollands & Pan, 2018). eSpark is an iPad-based learning tool used by over

60,000 people that provides a system of apps and videos similar to an intelligent tutoring system (Hollands & Pan, 2018).

There have not been many studies concerning the use of either tool. Longnecker (2013) assessed the use of IXL in middle school mathematics classes as a replacement for lessons, assessments, and review. The experimental group used IXL as a supplement to their classroom instruction while the control group's data was pulled from the same classroom, but from the previous year before the use of IXL. He concluded that the group using IXL showed no significant improvement compared to the control group. Hollands and Pan (2018) compared IXL to eSpark. In their study, with elementary math students, no significant differences in performance between the tools were found.

Summary of Examples of Adaptive Learning Tools

Based on the variety of studies discussed in this literature review, there has not been a clear indication that adaptive learning tools offer significantly improved learning gains over other instructional technologies. Some evidence has shown that these tools could benefit students by improving test scores and other facets of student achievement (Burns et al., 2012; Cheung & Lavin, 2013; Chu, 2018; Kulik & Fletcher, 2016; Li & Ma, 2010; Light & Pierson, 2014; Longnecker, 2013; Sun et al., 2018; Zengin, 2017). However, what was consistent in the research in both higher education and K-12 environments was that the tool was beneficial to students but no more so than what was already in place (Barrett, 2018; Campuzano et al., 2009; Griff & Matter, 2013; Hollands & Pan, 2018; Kelly, 2018; Kelly & Rutherford, 2017; Murray & Pérez, 2015; VanLehn, 2011). The majority of the research studies have primarily focused on quantitative measures and did not take into account how the tools were used for instruction. Like the research on other technologies, it is important that teachers study how an adaptive learning tool functions and have a plan of how to implement it (Liu, 2017). There is a need for studies that take into account the perspective of the teachers who use adaptive learning tools in order to explore the ways in which these tools are actually used in classroom instruction.

ALEKS

Since the focus of this study is on the ways that one particular adaptive learning tool (ALEKS) is used in high school classrooms, it is important to give some background information about this tool. It is also important to describe the theoretical foundation on which the tool was founded and to explore the suggested ways of using it. This section of the literature review focuses on the information posted on the ALEKS website and will include the viewpoint of the company itself regarding the intended use of the tools it offers and regarding the teaching strategies and implementation tactics it recommends to students and teachers. These strategies are then compared to what has been researched about teaching mathematics and successful technology integration.

Description of ALEKS

Adaptive learning tools are a form of artificial intelligence that takes input in the form of user feedback and generates personalized instruction. ALEKS is one of the more well-known adaptive learning tools used for mathematics. It is used by hundreds of thousands of high school students throughout the United States (ALEKS, 2020b). ALEKS uses its artificial intelligence to determine which topics a student is ready to learn and then assigns sequences of problems for those students to complete. These problems serve as knowledge checks for the program to analyze and gain information from, information then used to adapt instruction by introducing prerequisite skills (if needed) or by advancing to a new topic (ALEKS, 2020d). ALEKS can provide instruction by offering step-by-step guidance, but only after receiving a response from a student (Mills, 2018).

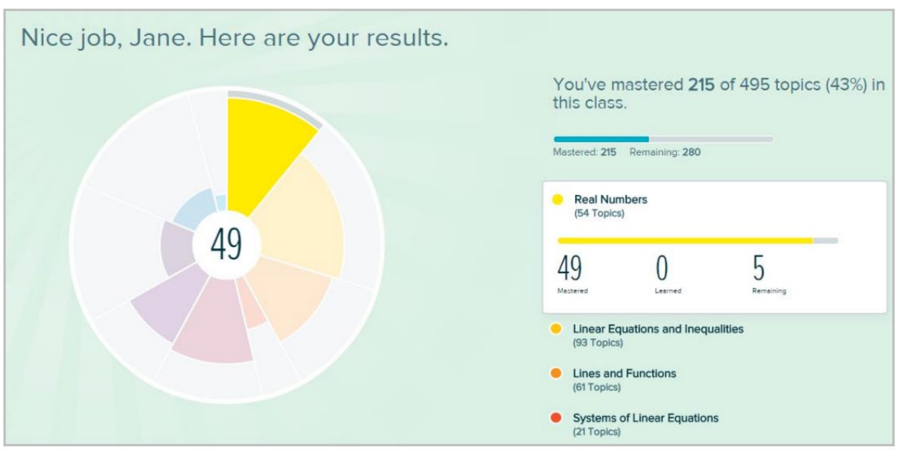
According to ALEKS (2020b), the operating procedure of their program begins with the assumption that students learn mathematics at their own pace. NCTM (2020c) has suggested that teachers should use previous evidence of student learning to adjust instruction. ALEKS has followed this idea by recommending that students begin the program with an accurate assessment of their knowledge so that they can build skills that they are ready to learn (ALEKS, 2020b). Based on the initial knowledge check, ALEKS then uses artificial intelligence to map out a pathway of topics that the student is ready to learn, preventing the frustration or boredom that comes from trying to learn material the student is unprepared for. As the student demonstrates that he or she can consistently get problems correct within a given topic, the program updates its map and chooses more topics to work on (ALEKS, 2020d). The program utilizes this loop of knowledge checks, updates to a learning map, and new problems until a learner proves mastery in all of the assigned topics.

ALEKS Tools

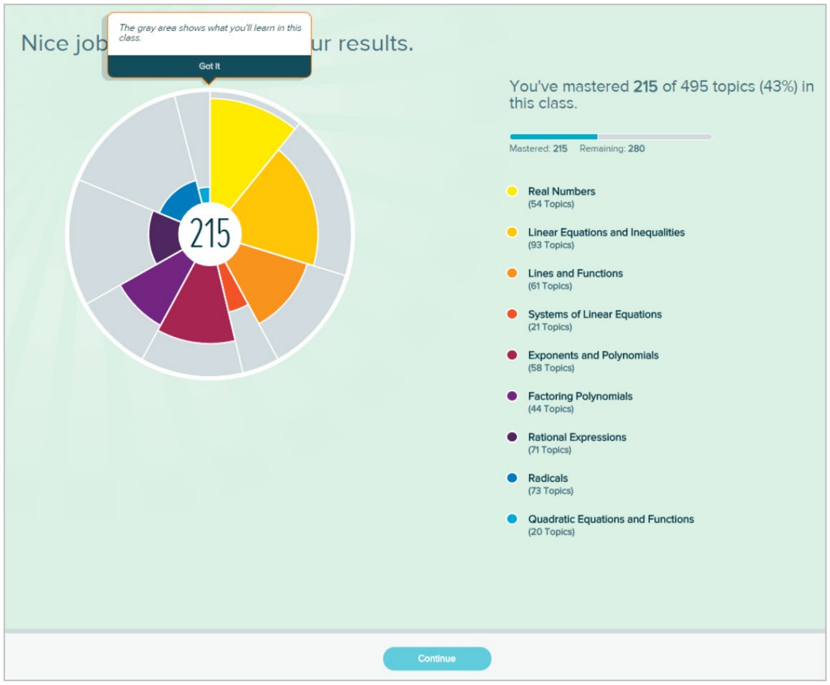
ALEKS has several features and tools that teachers can use to access student information. These tools can help teachers to monitor student progress, analyze class data, and track student engagement levels. There are also tools in ALEKS that provide immediate feedback and explanations for students, so they are able to complete learning tasks without the presence of a teacher. This section describes some of the tools that

ALEKS offers to teachers and students. The tools described in this section are relevant to the purpose of this study.

When students log into ALEKS for the first time they are required to complete an initial assessment. This initial assessment determines what mathematical topics a student knows (and does not know) and helps to build what is known as their ALEKS Pie Chart (ALEKS, 2021b). This pie chart displays their mastery level of topics assigned in the class and also topics that they still need to master. Teachers and students can use this information to set learning goals and monitor progress. Picture 2.1 and Picture 2.2 below show examples of the ALEKS Pie Chart from the student manual provided on the ALEKS website (ALEKS, 2021b).



Picture 2.1 ALEKS Pie Chart Example I



Picture 2.2 ALEKS Pie Chart Example II

Some other tools that teachers can use to monitor students are the progress reports. Teachers can pull up the progress of an individual student or their class as a whole. Teachers can use this information to assess student understanding of mathematical topics. They can also use these reports to follow the progress of a student through the complete set of topics in a class. Picture 2.3 displays an example of a progress report of an individual student that a teacher can access from the ALEKS Instructor's Guide (ALEKS, 2021a). Picture 2.4, also from the ALEKS Instructor's Guide, displays an example of a report displaying the results of a whole class on an assigned topic (ALEKS, 2021a).

Jennifer Alberti - Progress Report

Legend

Download

Last Login	Enroll Date	Hours per Week	Total Time in this Class
07/28/2016	04/19/2016	3.6	54h 3m

Pre-Algebra (Current Class) | All Classes

Knowledge Checks			Performance		Since Last Knowledge Check		
Reason	Start	Finish	Progress (Percent)	ALEKS Grade	Topics Learned	Hours in ALEKS	Topics Learned per Hour
Scheduled Assessment 2 Instructor Assigned Knowledge Check - Comprehensive	Jul 20	Jul 20 44m 43s	53 +3%		13	4.1	3.1
Instructor Assigned Knowledge Check - Comprehensive	Jul 5	Jul 5 31m 49s	50 +4%		19	8.7	2.2
Instructor Assigned Knowledge Check - Comprehensive	Jun 21	Jun 21 42m 56s	46 +5%		19	6.1	3.1
Scheduled Assessment 1 Instructor Assigned Knowledge Check - Comprehensive	Jun 6	Jun 6 31m 20s	43 +5%		22	7.2	3.1
Instructor Assigned Knowledge Check - Comprehensive	Jun 2	Jun 2 32m 7s	42 +1%		3	-	-
Instructor Assigned Knowledge Check - Comprehensive	May 19	May 19 33m 8s	38 +5%		19	6.5	2.9
Instructor Assigned Knowledge Check - Comprehensive	May 3	May 3 38m 2s	35 +5%		21	9.3	2.3
Initial Knowledge Check	Apr 19	Apr 19 31m 35s	31 +6%		21	6.6	3.2

Picture 2.3 Progress Report of Individual Student

Assignment Results (Student Scores)
Results currently available to the students.

Download Excel Spreadsheet

Quiz 2
View: Student Scores | Per Question Results | Detailed Student Results

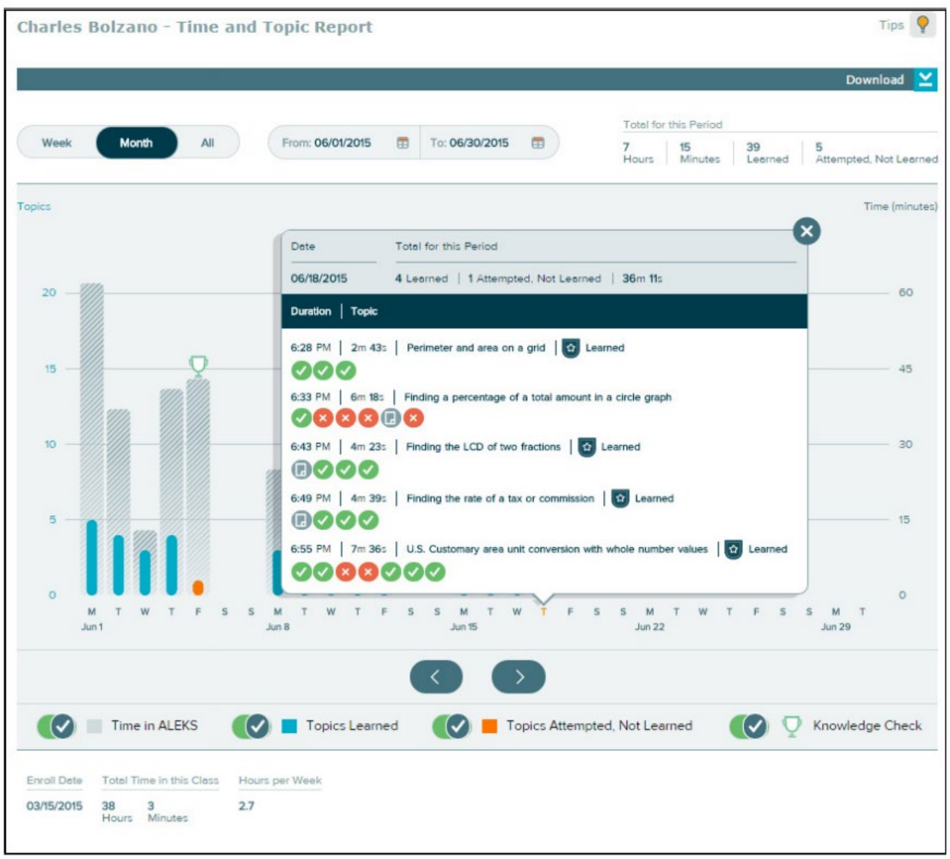
Class Average: 88%
(34 out of 34 students)

Send Message to Selected Students

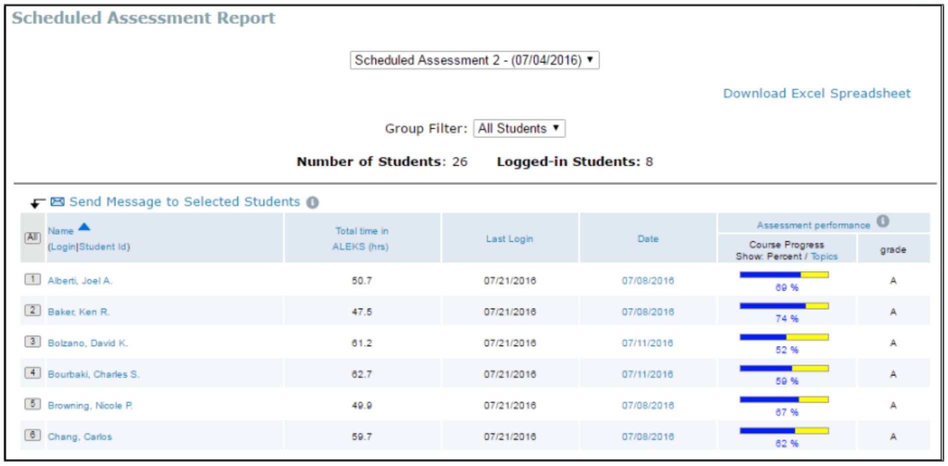
All	Student (Name | Login | Student_id)	Date Submitted	Score	Grade
1	Alberti, Kai P.	09/23/2013	100%	A
2	Alberti, Kevin	09/22/2013	88%	B
3	Alberti, Victoria K.	09/20/2013	88%	B
4	Baker, Tracy L.	10/02/2013	94%	A
5	Bolzano, David T.	10/01/2013	82%	B
6	Browning, Jennifer	09/24/2013	88%	B
7	Cameron, Jill E.	09/23/2013	88%	B
8	Carter, Cindy B.	10/01/2013	88%	B
9	Cauchy, Joel K.	09/30/2013	71%	C

Picture 2.4 Progress Report of Class

The reports generated in ALEKS can give teachers information beyond a percentage score or mastery level of a topic. For instance, the reports can provide teachers with the amount of time a student was engaged with ALEKS, the time it took them to complete an assignment, and even the rate at which they completed tasks on ALEKS. Picture 2.5 displays an example of an individual report of the topics addressed and time spent by an individual on ALEKS (ALEKS, 2021b). In this report a teacher can see the number of questions a student practiced, their success level, and the duration of time they spent on a topic. Picture 2.6 displays both the mastery level and the time spent on an ALEKS assignment (ALEKS, 2021a). This report gives teachers an overview of an entire class. These tools can provide insight for a teacher on student understanding and engagement.

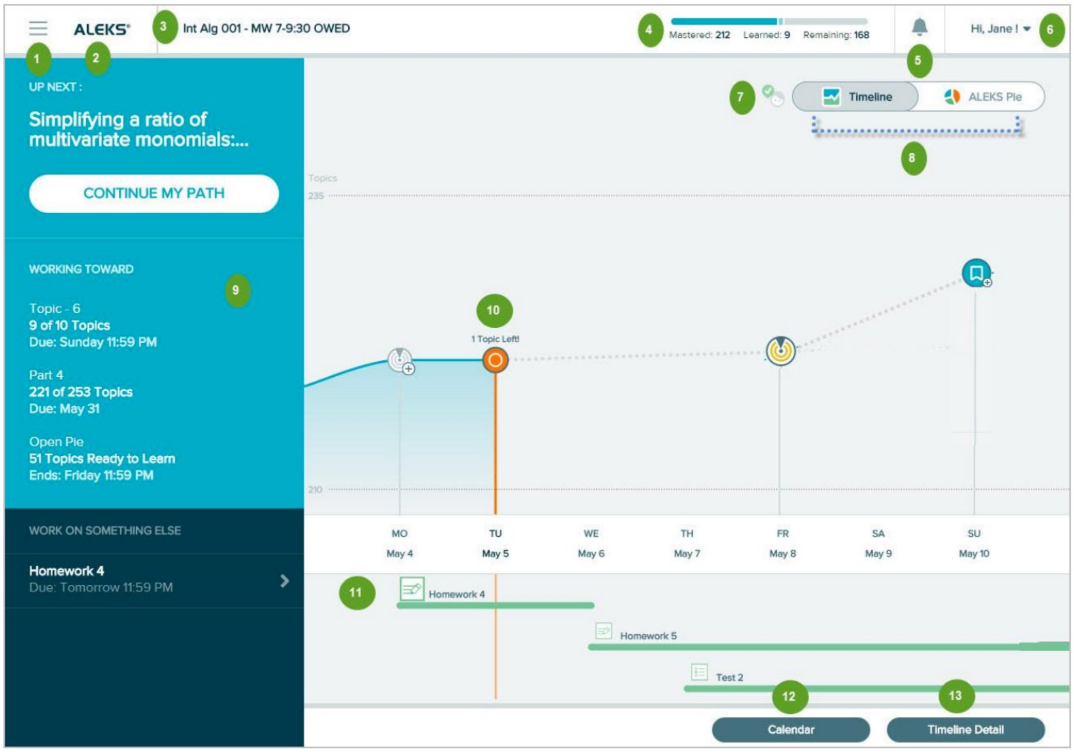


Picture 2.5 Time and Topic Report for Individual



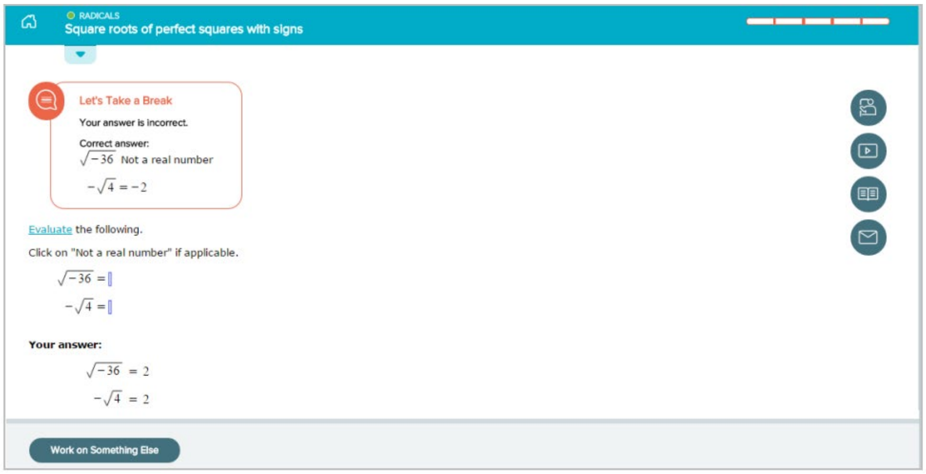
Picture 2.6 Time and Topic Report for Class

When students log into ALEKS they may choose to work on their My Path. The ALEKS My Path is where students can select topics to master in order to fill out their ALEKS Pie Chart. The My Path provides students with tasks to complete en route to mastering a topic as well as resources for managing their time and progress (ALEKS, 2021b). Picture 2.7 displays an example of what the ALEKS My Path looks like for students (ALEKS, 2021b).

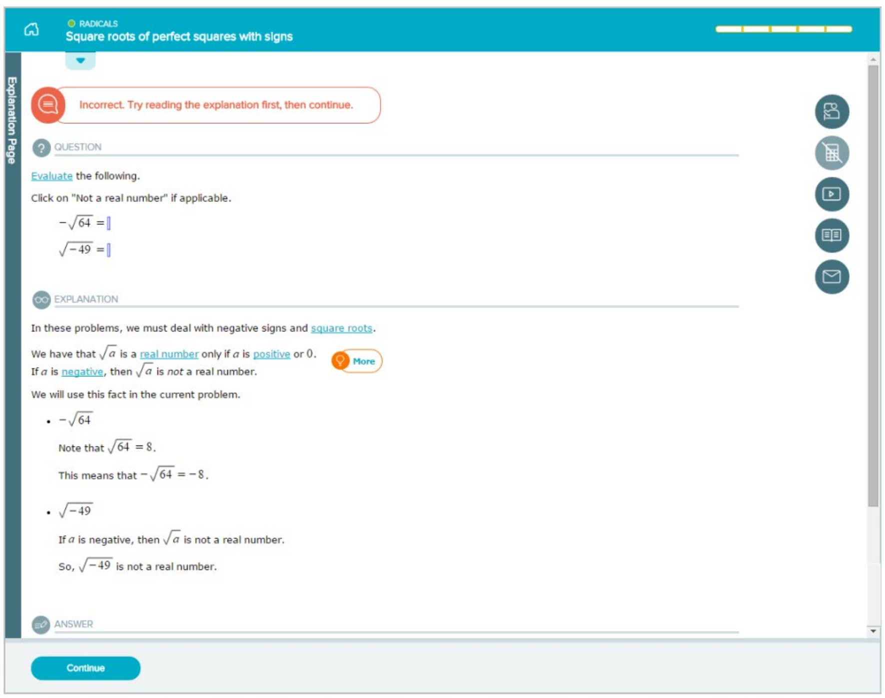


Picture 2.7 ALEKS My Path

When students are completing a task in ALEKS, there are several ways that the program offers assistance to students. ALEKS offers students explanations and immediate feedback when students input answers to ALEKS questions (ALEKS, 2021b). Picture 2.8 shows an example, from the Student Manual, of the specific feedback given to students when an incorrect answer is given (ALEKS, 2021b). This feedback can inform a student if their answer is right or wrong, provide hints, or offer students the option to click in the program to get a more detailed explanation. Picture 2.9 displays an example of a more detailed explanation in ALEKS (ALEKS, 2021b).



Picture 2.8 Sample Feedback of ALEKS Problem



Picture 2.9 Sample Explanation of ALEKS Problem

<u>Theoretical Framework of ALEKS</u>

According to ALEKS (2020d), the technology was developed by a team of mathematicians, software engineers, and scientists using a multi-million dollar grant. The program uses an artificial intelligence system that is based on the theoretical work of Dr. Jean-Claude Falmagne in the field of Knowledge Space Theory. The description of this theory, as provided by ALEKS (2020d), is that it applies concepts of combinatorics and stochastic processes to model fields of knowledge. Combinatorics is a field of mathematics related to counting and selecting objects out of a set while stochastic processes are a collection of random events. The ALEKS system takes an object of knowledge (like a mathematical concept) and organizes it into what is called the knowledge state of a student (ALEKS, 2020d). Since this knowledge state can be composed of millions of unique structures, a computer algorithm is used to create it.

One way to understand how the idea of a knowledge state works is to look at it as the complete list of mathematical problems a student is capable of solving. The computer algorithm assesses a student and determines what they can do and what they are ready to learn (Falmagne et al., 2006). A classroom teacher does the same thing when working with students by applying questioning techniques or by grading an assessment. ALEKS is able to assess and provide feedback to a student instantly. This instant feedback has been shown by evidence to be helpful for student learning (Corbett & Anderson, 2001; Marzano et al., 2001; Schute, 2008). In addition, there may be hundreds of thousands of potential topics that a student already knows or is ready to learn, and the computer algorithm is able to provide a personalized pathway for that student (Falmagne et al., 2006). As the student continues to progress through the tool, the computer system can collect more data and recognize patterns in learning (Taagepera & Noori, 2000). The more data the system collects, the more the knowledge space adjusts, which can provide the tool and teachers with ways to deliver further instruction (Falmagne et al., 2007).

Recommendations for Teachers

Even though ALEKS is able to assess, provide feedback, and give instruction to students, the company has acknowledged the importance of the teacher in supporting its use. ALEKS has provided guides for teachers that recommend how to use the program and relate the instructional strategies that they deem effective (ALEKS, 2020a). It should be noted that these recommendations have been provided by ALEKS and are not directly supported by research. However, many of their strategies match what is considered to be effective instruction and proper use of technology when teaching mathematics. One example given was the way that ALEKS has viewed the role of the instructor. ALEKS has supported a teacher taking an active role in the monitoring of a student's progress by providing classroom management through structure, support, and reinforcement. Their teacher guide has suggested that teachers use their classroom time more for instructional purposes than for managing classroom materials and providing directions for a learning task (ALEKS, 2020a). These instructional practices could be checking student work to provide feedback, engaging in a mathematical discussion, or developing alternate problem solving strategies. As suggested by supporting literature, a teacher fully implementing technology needs to adjust their teaching style to be a facilitator of student-centered learning (Bray & Tangney, 2017; Levin & Wadmany, 2006; Monaghan, 2004).

For classroom teachers that use ALEKS, the company has provided several recommendations of teaching strategies and activities (ALEKS, 2020c). These suggestions do not have specific evidence supporting their use, but one can argue that effective teaching strategies are components of these suggestions. The first suggestion is a "supervised math lab" where a teacher allows students to work on ALEKS during a period of time and provides direct instruction and assistance when prompted from a student (ALEKS, 2020c). This is similar to “self-paced learning” and “distance learning” where a student works on ALEKS independently and the teacher provides assistance when needed (ALEKS, 2020c). In these scenarios, students and teachers are expected to communicate regularly about progress, challenges, and needs. For in-class teachers, small-group instruction was also a recommended practice. In this scenario, a teacher would use the ALEKS tools to group students by topic and to provide focused instruction to each group while the other students engage in self-paced learning. In all of these strategies, ALEKS (2020c) has recommended that the teacher make use of the data available on student performance in order to make classroom decisions.

Instead of listing specific strategies, ALEKS has interviewed classroom teachers about how they use the program, what recommendations they have for successful implementation, and how much they supplement with other types of instruction (ALEKS, 2020a). These interviews came from several types of high schools, several different classroom environments, and featured various levels of ALEKS implementation. The interviews all showed unique ways of using the tools, but there was a consistent theme of using ALEKS to supplement other forms of instruction. Nearly all of the teachers made suggestions that were in line with what the literature has suggested is effective instruction: (1) setting goals, (2) understanding how the technology works and having a plan for its use, and (3) implementing classroom management strategies (Anthony & Walshaw, 2009; Bartell et al., 2017, Caro et al., 2016; NCTM, 2020a). It is important to note that although these strategies came from classroom teachers using ALEKS, their source is the company's own publication. The need for peer-reviewed research into how

ALEKS is used would make an important addition to the body of literature regarding adaptive learning tools.

Summary on ALEKS

ALEKS is a form of adaptive learning used by hundreds of thousands of students in the U.S. (ALEKS, 2020b). The tool uses artificial intelligence to determine what a student is ready to learn and assigns problems for students to work on (ALEKS, 2020a). As students progress with the tool, the program updates its learning map with a loop of knowledge checks and questions until mastery is achieved (ALEKS, 2020a; Taagepera & Noori, 2000).

The program is based on the Knowledge Space Theory of Dr. Jean-Claude Falmagne. This theory uses combinatorics and stochastic processes to create a knowledge space of what a student can do and is ready to learn (ALEKS, 2020d; Falmagne et al., 2006). In ALEKS, this is applied using artificial intelligence since the knowledge state of an individual could be composed of millions of structures.

Although ALEKS is able to provide feedback and instruction to students, the company has acknowledged the need for the program to be used in conjunction with teacher support. They have provided several publications on their website which have suggested that teachers act as facilitators while using the tool (ALEKS, 2020c). They also have provided accounts from actual mathematics teachers that described how these teachers use it in their classrooms and their suggestions for successful implementation (ALEKS, 2020a). However, outside of these descriptions provided by the company itself, there has been little research that describes how the tool is used by mathematics teachers.

Research Studies with ALEKS

The recommendations from ALEKS (2020a) have described the ways in which teachers have used the tools and have also offered suggestions of how to use it successfully. However, since these publications are not from peer-reviewed sources, it is important to investigate the current research related to ALEKS. This section synthesizes the research that is relevant to the use of ALEKS in high school math classrooms. The research presented in this section will describe different settings in which the tool has been used, its effectiveness for academic achievement, and descriptions of the experiences of the teachers using it.

<u>ALEKS and Academic Achievement</u>

Some research has emerged in recent years regarding the use of ALEKS in classrooms. Much of what has been written centers around the connections between ALEKS and academic achievement. One of the first studies using ALEKS was conducted in a 14-day summer school session for Algebra I students. Students showed evidence of learning gains on an Accuplacer assessment (Sabo et al., 2013). The 31 students in this study used ALEKS for four hours per day, and those results were measured against those of an intelligent tutoring system. No significant difference was found between the two systems, but all students participating displayed learning gains in their knowledge of arithmetic and algebra. Goodwin (2017) explored using ALEKS in a freshman engineering class, with his study showing improved learning gains from students. This study used ALEKS as a summer intervention for incoming students. The students who spent more time using the program in preparation for the course outperformed those who did not as measured by class grades. In a Yilmaz (2017) study, middle school students used ALEKS for 45 minutes per day, and the use of the tool was found to help to improve mathematical achievement. His study used a quasi-experimental design with 1,110 students from fifth through ninth grade. The experimental group used the tool for 45 minutes per day as a part of their school day while the control group did not use it. Student performance was measured using the NWEA MAP test for mathematics as a pretest and posttest. Students using ALEKS outperformed the non-ALEKS-using group. Karner (2016) compared four years of high school Algebra I students, using the EXPLORE to PLAN assessment to determine whether ALEKS had an effect on growth. The EXPLORE to PLAN assessment is a curriculum-based assessment for mathematics from American College Testing (ACT) designed for high-school aged students (ACT, 2009). Karner used a pre-post quasi-experimental design in his study. The treatment group took an intervention class using ALEKS along with an Algebra I class while the control group took Algebra I with no ALEKS intervention. He found that ALEKS users had higher levels of improvement on the EXPLORE to PLAN assessment than the non-ALEKS users. These four studies have provided some evidence that the tool can be effective in multiple settings.

Not all studies have pointed to the ALEKS system displaying an increase in student learning, however. Several studies have also shown inconclusive results or no correlation between its use and student performance (Nwaogu, 2012; Mills, 2018; Richard, 2019). Richard (2019) used a mixed-methods study to investigate the use of ALEKS and student performance on the LEAP 2025 mathematics assessment. The results of this study did not show that the amount of time a student spent using ALEKS had an impact on assessment scores. A similar study tried to connect the amount of engagement time a student had with ALEKS with an improvement in test scores (Mills, 2018). This study used PSAT scores as the indicating variable for student performance. The results showed that engagement time and topics mastered in ALEKS did not have a significant impact on the students' PSAT math scores. Fang et al. (2019) conducted a meta-analysis of 15 studies between 2005 and 2015 to assess the effectiveness of ALEKS on student learning. Their findings indicated that there was not a significant difference when ALEKS was compared to traditional learning approaches across several school settings, assessment types, and implementation strategies. However, it should be noted that all of the studies used in the meta-analysis are over five years old and improvements of ALEKS in terms of technology quality and implementation may have taken place since then.

Some evidence has shown that the use of ALEKS produced improvements in academic performance, but there have also been studies that have not shown a significant difference. There is a need to study the ways that teachers use ALEKS in their classrooms to make a connection between the instructional practices and the use of the tool. There is also a need to collect data on the perceptions of teachers on the effectiveness of ALEKS. Having research on the teaching strategies used and the attitudes of teachers towards its use can help to determine the circumstances under which ALEKS can be used effectively in high school mathematics classrooms.

Experiences of Teachers

Since this research study focuses on the experiences of teachers using ALEKS, it is important to investigate the research conducted about how the tool has been used in a classroom setting. There has not been much written on the specific ways that ALEKS has been implemented by teachers. Perhaps the most thorough examples of studies showing how ALEKS has been used have come from the company itself. ALEKS has published recommendations for how teachers should implement their system, and some testimonials from actual educators have been featured on their website (ALEKS, 2020b). They also have published a webpage with 14 classroom situations and advice on how the ALEKS system can be used as an option for teachers in those situations (ALEKS, 2020a). These sources provided some idea of what research into the teaching and learning strategies that align with using the tool might look like. However, it is difficult to consider these sources reliable since they have come from the company's own website.

As for peer-reviewed research, there has not been much done in this area. The subject has gained more attention recently, however. Many of the research studies conducted on ALEKS have focused on assessment scores and have neglected to consider the strategies used by the teacher and the teacher's perceptions of the system. If a teacher does not believe that the tool has a benefit for student learning then its implementation level will suffer (Hsu & Chang, 2013). As for studies that have investigated how ALEKS is used in classes, there have been a few examples.

The following studies are amongst the few that have attempted to describe how ALEKS has been used in instruction. Although these studies do not directly describe the way in which ALEKS has been used, they at least mentioned the role of the teacher. Craig et al. (2013) implemented ALEKS with 291 sixth-grade students over a 25-week period and measured results using a standardized test. Students in this study used ALEKS for 20 minutes while another group received instruction from a teacher for the same allotted time. The teacher in the ALEKS classroom was present to supervise and assist with technical issues. The teacher in the non-ALEKS group followed a I-Do, We-Do, You-Do technique for teaching in their 20 minute sessions. The results of this study have indicated that there is some evidence of the ALEKS program being more effective than the instruction from a teacher. Padilla-Oviedo, Mundy, and Kupczynski (2016) used collaborative learning strategies with ALEKS in a college algebra class. They defined collaborative learning as small group activity aimed at the completion of a common goal. Their study placed students into three groups: a group using ALEKS independently, a group not using ALEKS at all, and a third group using ALEKS with a collaborative learning strategy. They concluded that the group using ALEKS with the collaborative learning strategy performed the best in terms of their final grades in the course. These studies have shown some examples where the role of the teacher has been described or where a teaching strategy has been considered. Although these studies have shown, to some extent, the role of the teacher in using ALEKS, there is still a need for more research on how the tool is used in the classroom.

Some recent studies have tried to look into student behaviors and attitudes toward using ALEKS. Wang et al. (2018) investigated student learning strategies using ALEKS, showing that higher-achieving students practiced better learning behaviors than lower-achieving students when using the feedback resources provided within ALEKS. Serhan (2017) attempted to collect data on the attitudes of students using a Likert-style questionnaire and found that students had a positive attitude towards using the tool. Xu, Meyer, and Morgan (2009) conducted a study with qualitative data on the experiences of students using ALEKS in a college math class. Their study showed that the highest performing group favored the assessments in ALEKS while students in the middle to low-performing groups had negative opinions about the program. The main complaint among the students was frustration regarding how the program functions from a technical standpoint. Even though these studies showed the perceptions of users of the ALEKS system, they do not address the attitudes of the teachers.

Benjamin (2020) attempted to collect qualitative data on the perceptions of teachers using ALEKS and to determine how often the tools were used and in what capacity, using a Likert-scale survey with 2,477 math teachers. The results of the study showed that teachers mostly used the adaptive learning tools in their classrooms as a supplement for extra practice or review. Their research also showed evidence that teachers rarely used adaptive learning tools for whole or small group instruction. Benjamin (2020) studied teachers' perceptions of the advantages and disadvantages of the adaptive learning tool, ALEKS, by using an open-ended questionnaire. Most of the teachers felt that the tool addressed student differences, improved retention, and enhanced the learner experience. Benjamin (2020) stated that these positive outcomes matched what has been supported in previous literature as well.

Summary of Research on ALEKS

The studies outlined in this section have described many of the potential benefits of the ALEKS system in a variety of classrooms. Many studies have followed a quasi-experimental design aimed at determining the effectiveness of ALEKS for improving test scores in mathematics (Karner, 2016; Sabo et al., 2013; Yilmaz, 2017). However, the research has been unclear about whether using the tools as an intervention has impacted student learning (Fang et al., 2019; Goodwin, 2017; Mills, 2018; Nwaogu, 2012; Richard, 2019). There have been some studies that discuss how the tool has been used by teachers, but there has not been enough evidence to draw conclusions (Benjamin, 2020; Padilla-Oviedo et al., 2016). In particular, there has been little information, outside of the accounts from the ALEKS company itself, of how teachers are actually using the tool. Nor has there been any research on the perceptions of teachers regarding how easy the tool is to use or of how useful it is for student learning. The review of the literature suggests that further studies need to be conducted to help fill the gap in research related to how ALEKS is used in high school classrooms.

Chapter 2 Summary

The purpose of this literature review was to determine what current research exists related to teaching mathematics using adaptive learning tools. This study addresses gaps in the research related to the pedagogy of teachers and their perceptions of the potential added benefits of using adaptive learning as a part of their core curriculum. TAM serves as the theoretical framework for this study. TAM has stated that teachers will only use the technology tools if they are perceived to be both easy to use and perceived to offer an additional benefit to student learning (Davis, 1989). The Knowledge Space Theory is the foundation of ALEKS and has outlined the process for collecting and organizing student data into learning pathways for students based on what they know and what they are ready to learn (Falmagne et al., 2006).

The purpose of this chapter was to review the research related to the teaching of mathematics, implementing technology, and adaptive learning tools. This literature review was able to reveal several themes and trends across each of these topics. In terms of the research related to teaching mathematics, there has been significant evidence that effective teaching strategies support student mathematics learning. These teaching strategies are: a focus on reasoning and problem solving, classroom management techniques, and immediate and detailed feedback to students (Anthony & Walshaw, 2009; Arends et al., 2017; Bartell et al., 2017; Caro et al., 2016; Hattie, 1999; Hattie & Timperley, 2007; Havnes et al., 2012; NCTM, 2020a).

Many of these teaching strategies are enhanced by the use of technology. The current research has shown evidence that technology tools for teaching mathematics allow for students to perform calculations and graphing techniques more efficiently, manipulate larger and more realistic sets of data, and develop mathematical models (Sen & Ay, 2017; Wachira & Keengwe, 2011). These capabilities allow students to engage in more problem solving and reasoning activities (Caro et al., 2016; NCTM, 2020c; Sen & Ay, 2017). The literature has also shown that teachers must overcome barriers related to their own teaching beliefs and their perceptions of technology use (Kopcha, 2012; Pierce & Ball, 2009; Wachira & Keengwe, 2011). However, teachers who hold strong beliefs about the effectiveness of technology and who have confidence in their ability to use it can overcome these barriers (Karatas et al., 2017; Kopcha, 2012; Pierce & Ball, 2009; Wachira & Keengwe, 2011).

Adaptive software programs are technological tools that, through their ability to assess, diagnose, and provide feedback and instruction for students, can help a teacher be an effective facilitator (Bulger, 2016; Hsieh, Lee, & Su, 2013; Murray & Pérez, 2015). Although studies have been mixed in terms of outcomes, there have been several that have shown a correlation between the use of adaptive learning systems and enhanced academic achievement in mathematics classrooms (Burns et al., 2012; Cheung & Lavin, 2013; Chu, 2018; Li & Ma, 2010; Kulik & Fletcher, 2016; Light & Pierson, 2014;

Longnecker, 2013; Sun et al., 2018; Zengin, 2017). Even though there has been a significant amount of research on the academic effects of adaptive learning tools, very few studies have attempted to collect qualitative data regarding how teachers use these tools and what their perceptions are of their effectiveness.

One of the adaptive learning tools used in mathematics classrooms is ALEKS. ALEKS is a sophisticated system used by hundreds of thousands of students to support the learning of mathematics (ALEKS, 2020b). As with other adaptive learning tools, there have been several research studies that have attempted to measure ALEKS's effect on mathematics achievement with mostly mixed results (Fang et al., 2019; Goodwin, 2017; Mills, 2018; Nwaogu, 2012; Richard, 2019). Outside of the publications presented by ALEKS itself, little has been done in terms of researching how teachers use ALEKS as a regular component of their classrooms. This study helps to fill gaps in the literature by providing evidence from actual cases of teachers using the ALEKS system and by collecting information on the perceptions of teachers using it.

CHAPTER 3: METHODOLOGY

Introduction

The purpose of this study was to understand the teaching strategies used by high school mathematics teachers who used ALEKS in their classrooms and to examine their perceptions of its ease of use and usefulness. A qualitative approach was used so that information about the teachers' experiences, teaching strategies, and perceptions was able to be analyzed. This study helped to fill research gaps related to the field of adaptive learning tools because it investigated actual accounts of the teachers, using them and their voices. The results of this study can be used by schools, teachers, and technology companies to enhance the use of adaptive learning tools in mathematics classrooms.

One of the gaps in the literature on adaptive learning tools in mathematics classrooms is the absence of user voices, a problem which requires qualitative research to solve. The literature on effective mathematics teaching practices has been extensive (Anthony & Walshaw, 2009; Bartell et al., 2017; Caro et al., 2016; Hattie & Timperley, 2007; NCTM, 2020c; Shute, 2008). There is also considerable support for utilizing technology in support of the teaching of mathematics (Sen & Ay, 2017; Wachira & Keengwe, 2011). However, there has not been much research on whether these practices and strategies are actually being used by teachers when equipped with ALEKS as their core curriculum tool. Nor have there been research studies that have attempted to analyze the perceptions of teachers who use the ALEKS system. This study adds to the body of literature related to adaptive learning tools by taking a qualitative approach to collecting and analyzing information from the teachers involved with their use.

Statement of the Problem

The literature related to adaptive learning tools has shown some evidence that they could be useful for improving student learning (as measured by test scores) when used as an intervention or as a supplement to other teaching strategies (Bochniak, 2014; Burns et al., 2012; Cheung & Slavin, 2013; Longnecker, 2013). However, few studies have attempted to research how educators have implemented teaching strategies while using adaptive learning systems. There has been significant evidence connecting effective teaching strategies and student learning (Anthony & Walshaw, 2009; Bartell et al., 2017; Caro et al., 2016; Hattie & Timperley, 2007; NCTM, 2020c; Shute, 2008). Technology implementation has also shown positive outcomes when it is supported by teachers who believe it to be easy to use and useful for their teaching (Bray & Tangney, 2017; DeWitte & Rogge, 2014; Ertmer et al., 2012; Levin & Wadmany, 2006). Despite the literature supporting the positive effects of teaching strategies and technology integration, there has been a limited amount of research on how teachers are using adaptive learning tools.

The goal of this study was to reduce the gap in the research related to adaptive learning tools by using qualitative methodologies to determine how teachers used a specific adaptive learning tool, ALEKS. Some studies have shown the use of ALEKS correlating with improved test scores (Goodwin, 2017; Karner, 2016; Yilmaz, 2017), while others have shown no difference between instruction with ALEKS and instruction without it (Mills, 2018; Nwaogu, 2012; Richard, 2019). Since the analysis based on test scores has been mixed (and given the connection between student learning, teaching strategies, and technology use) it is important to research how the tool is actually used by teachers for instruction. (Anthony & Walshaw, 2009; Arends et al., 2017; Bartell et al., 2017; Caro et al., 2016; NCTM, 2020c; Sen & Ay, 2017). The ways in which ALEKS is used have only been explored in publications provided by the company, so there is a need for independent research (ALEKS, 2020a; ALEKS, 2020c). This study also collected data on the teachers' perceptions of how easy to use and useful they believed the tool to be. Teachers play a significant role in student technology use and the effectiveness of technology implementation, so collecting their views is an important addition to the field of research (Anthony & Walshaw, 2009).

The ALEKS system is used by tens of thousands of teachers and millions of students in the United States (ALEKS, 2020b). Schools spend hundreds of thousands of dollars on technology and training each year (Davis, 2019). Poorly implemented technology can hinder support from teachers and can have a negative impact on student learning or have no impact at all (Pierce & Ball, 2009; Wachira & Keengwe, 2011). The research presented in this study can help schools, teachers, and technology companies to develop buy-in and effective professional development for the use of ALEKS. Since little research has attempted to seek the voice of teachers or has collected data on how it is actually used in classrooms, this study provides meaningful information for numerous stakeholders.

Research Questions

The research questions in this study address gaps in the literature related to adaptive learning tools. There is a need for qualitative research to collect teachers' views on the ways in which they utilize adaptive learning tools. The purpose of this study was to understand the teaching strategies high school mathematics teachers used with ALEKS in their classrooms and to examine their perceptions of its ease of use and usefulness. The goal of this study was to answer the following questions:

1) What teaching strategies are high school mathematics teachers implementing while using the adaptive learning tool, ALEKS?
2) How do high school mathematics teachers perceive the ease of use of the adaptive learning tool ALEKS in their classrooms/classes?
3) What are high school mathematics teachers' perceptions of the usefulness of the adaptive learning tool, ALEKS in high school mathematics classes?

In order to answer these research questions, five high school mathematics teachers participated in three interviews over the course of an academic school year. Merriam and Tisdell (2016) have suggested that the questions that are asked in qualitative interviews come from the theoretical framework of the study. Table 3.1 below outlines the research questions, their connection to elements of the theoretical framework (TAM: perception of ease of use and usefulness), and some samples of interview questions that will be asked of teachers. The complete list of interview questions are listed by interview in Appendix A-C.

Table 3.1 Research Question Description

Research Questions	Framework Elements	Data Collection (Interview Questions)
What teaching strategies are high school mathematics teachers implementing while using the adaptive learning tool, ALEKS?	System Design Features	Sample Question from Interview 1: During this school year, what teaching strategies did you plan to use with ALEKS in your mathematics classroom? Sample Question from Interview 2: What teaching strategies have you used with the ALEKS system in your classrooms this school year? Sample Question from Interview 3: Looking back at your use of ALEKS throughout the school year, describe how you used ALEKS in your teaching this year in terms of providing instruction?
How do high school mathematics teachers perceive the ease of use of the adaptive learning tool ALEKS in their classrooms/classes?	Perceptions of Ease of Use	Sample Question from Interview 1: What are your perceptions of how easy to use ALEKS was going to be as a tool this school year? Why do you think that? Sample Question from Interview 2: How easy has it been to use ALEKS for teaching your mathematics class? Sample Question from Interview 3: Reflecting on all of the ways you have used ALEKS, how easy ALEKS was to use for teaching your class?

Research Questions	**Framework Elements**	**Data Collection (Interview Questions)**
What are high school mathematics teachers' perceptions of the usefulness of the adaptive learning tool, ALEKS in high school mathematics classes?	Perceptions of Usefulness	Sample Question from Interview 1: What are your perceptions of how useful ALEKS was going to be as a tool this school year? Sample Question from Interview 2: How useful has ALEKS been for you to deliver instruction? Sample Question from Interview 3: Reflecting on your experience this school year, which ALEKS tools do you perceive were the most useful?

Research Methodology

This study followed a basic qualitative design in its methodology. Caelli, Ray, and Mill (2003) has described a basic qualitative study by defining it in the negative as "not guided by an explicit or established set of philosophic assumptions in the form of one of the known [or more established] qualitative methodologies'' (p. 2). Merriam and Tisdell (2016) have suggested that basic qualitative design is interested in how people interact, in how they construct their worlds, and in what meaning they attribute to these experiences. They have suggested that the researcher is interested in how meaning is constructed and not discovered. Basic qualitative designs are inductive and comparative, using coding, categorization of data, and analysis of themes (Kahlke, 2014). Some of the main characteristics of a basic qualitative design are that it uses purposeful sampling, performs data collection via interviews, and it provides a rich description of themes and categories (Merriam & Tisdell, 2016).

This approach best supports the purpose of the research because it focuses on teachers' experiences and perceptions (Creswell & Poth, 2018). The research problem that this study addressed was to gain an understanding of the teaching strategies teachers used with the ALEKS system and to learn about their perceptions of the ease of use and usefulness of the tool. The best approach to properly collecting and analyzing the data, to answering the research question, and to meeting the purpose of this study is a qualitative one. Creswell and Creswell (2018) have described qualitative research as research that explores and understands the meaning that individuals or groups ascribe to a social or human problem. A qualitative approach explores the meaning that individuals develop as they come to an understanding of their experiences through reflection (Creswell & Creswell, 2018; Fossey et al., 2002; Punch, 2013).

This research study used interviews with open-ended questions and conversations with actual high school mathematics teachers who used the ALEKS system. These interviews helped the researcher to gain an understanding of the setting, actions, and opinions of the teachers who have implemented ALEKS in their classrooms. By using interviews as the source of data, this study allowed teachers to share their experiences in their own voice and language (Seidman, 2006). Interviews were an appropriate method for this study because they helped the researcher to gain insight into the topic in teachers' own voices and also to develop a deep understanding of the teachers' experiences (Fossey et al., 2002; Siedman, 2006). This was especially helpful in this study because teachers shared information from their own schools and classrooms. An interview format can encourage participants to share details of their experiences that they might otherwise feel uncomfortable sharing (Fossey et al., 2002; Ryan et al., 2007).

Participants

The participants of this study were five high school mathematics teachers chosen using purposeful sampling procedures. Purposeful sampling is appropriate for qualitative research in general and for this study in particular since the participants need to meet the specific parameters of the research topic (Anney, 2014; Elo et al., 2014; Fossey et al., 2002; Miles, Huberman, & Saldana, 2020).

In order to take part in this study the participants needed to meet several requirements. Participants needed to be: (1) teaching a high-school-level mathematics classroom that used ALEKS as its core curriculum for a full academic year; (2) available and willing to meet for remote interviews outside of their regular working hours; (3) experienced with ALEKS, with at least one year using the tool or having received formal or informal training from an ALEKS professional, help from an experienced colleague, or self-training that used digital resources provided by ALEKS; and (4) experienced teachers, with at least two years spent teaching high school mathematics.

Qualitative samples can begin with a small number of participants so that the researcher can analyze the data during the course of the study to determine if saturation has occurred (or not occurred) and then decide if more participants are needed (Ryan et al., 2007). Fossey et al. (2002) have suggested that no fixed number of participants is necessary to conduct qualitative research as long as a sufficient amount of information is collected. A request for volunteers was sent via email to school administrators throughout the Chicagoland area. Ten candidates emerged from the request, and after screening interviews took place, five respondents who were willing to participate (and had approval from their school districts) were selected. During the screening interview, potential participants were informed of the requirements of the study, its purpose, and what the results were to be used for. This screening also confirmed that the teachers who were willing to be a part of the study met the criteria needed for the study. From the list of potential participants, five teachers were chosen who met the requirements of the study. Some of the participants did not meet the criteria and some did not have permission from their school district to proceed in the study. Teachers were chosen from a variety of backgrounds in terms of their teaching experience, their gender, and the courses that they used ALEKS with. Once participants were selected, permission was obtained from the schools and teachers. Participants' school districts had no official policy or requirement for ALEKS to be used: the program was selected for use by the participants themselves. In some instances, however, teachers were required to use ALEKS per the recommendation of a local community college.

Data Collection

Three interviews with each participant were conducted in a semi-structured format, with some questions established in advance and shared with participants. Interviews also included follow-up questions based on earlier participant responses. This style of interviewing followed broad themes that helped to direct the conversation toward the topics that the researcher was hoping to explore (Qu & Dumay, 2011). In this case, the researcher directed the conversation toward the specific ways ALEKS was used and toward the teachers' perceptions of ease of use and usefulness. This style of interview offered several benefits for the researcher in the data collection process. Fossey et al. (2002) believed this format to be useful because it allows a researcher to follow the themes of the research topic while still allowing the flexibility to ask different questions and to probe for more details in an explanation. A semi-structured interview can also be beneficial because it can seem more conversational, allowing for participants to feel more comfortable sharing information (Fossey et al., 2002; Knox & Burkard, 2009; Qu & Dumay, 2011). Since this study aimed to have teachers share their experiences, it was critical that the data collected be representative of the participant's own voice (Qu & Dumay, 2011).

A multi-interview approach was also chosen due to several benefits. Seidman (2006) recommended this approach because it allows a researcher to develop a deeper understanding of the context of a situation, and it helps the participant and researcher to develop trust. Since teachers needed to share details of their classroom experiences, establishing trust was important to the interview process. The multi-interview format has been recommended as helping to build relationships between the researcher and the participants (Knox & Burkard, 2009; Qu & Dumay, 2011). Fossey et al. (2002) have stressed the importance of building trust so that both the researcher and participants can be honest and open with each other. Another benefit of performing multiple interviews is that they allow the researcher to analyze data between rounds so that questions can be adjusted and themes can be explored more deeply (Fossey et al., 2002; May, 1991). Although each round of interviews had an outline of questions to be asked, changes were made as the data collection and analysis process began. The outline of interview questions was shared with teachers at least one week prior to the interviews.

The first interview with teachers took place within the first month of the school year. Seidman (2006) has recommended that the first interview be used for collecting background information relevant to the research topic. During this interview, the researcher asked teachers to share their experiences and perceptions of ALEKS prior to the start of the school year. The interview also asked teachers to share their plans for how they intended to implement ALEKS in their classrooms during the current academic year. This included questions about which teaching strategies they planned on using, how they intended to make use of the tools available in ALEKS, and why they made particular decisions regarding the tool. These questions provided the researcher with data on the backgrounds of the participants, their intentions for how they would use ALEKS, and their initial perceptions of how easy to use and useful the tools would be. An outline of the questions that were asked in the first interview can be found in Appendix A.

The second interview took place six weeks after the first interview and collected data on how teachers have actually been using ALEKS in their classrooms. The recommended purpose of this interview was to focus on the details of the experiences of the teachers (Knox & Burkard, 2009; Seidman, 2006). The questions used for this interview are outlined in Appendix B. In between interviews, changes were made to the interview outline and to follow up questions in order to provide more detail about a response or to provide more clarity in an explanation. This interview asked teachers to share what specific teaching strategies they had implemented in their classrooms while using ALEKS. These questions asked details about how, in their daily teaching tasks, they used the data collection, assessment, and feedback features of the ALEKS system. They were asked to compare their current use of ALEKS with their intentions at the beginning of the school year. In this round of interviews, teachers were asked to give their perceptions of how easy to use and how useful ALEKS (and the teaching strategies they have used with it) had been.

Seidman (2006) has recommended that the final interview be reflective in nature, that it allows participants to consider the meaning of their experiences. It can also serve as an opportunity to provide clarity or more detail to content analyzed by the researcher (Knox & Burkard, 2009). The final interview took place another six weeks after the second interview. This interview also followed an outline and asked teachers to reflect on their experiences and on their overall perceptions. The outline for this interview can be found in Appendix C. The purpose of the final interview was for teachers to share their perceptions of what teaching strategies they used and to comment on the level of ease of use and usefulness of ALEKS and of the accompanying strategies. They were also asked to share their opinions about how effectively they used ALEKS. This interview helped to synthesize their collective thoughts and perceptions regarding the research questions of the study.

The researcher met digitally with the study participants to discuss the parameters of the study and explain its intentions. This was an important step to take in the research process due to Internal Review Board (IRB) regulations, and it ensured that participants were informed of the goals of the study, of their rights, and of how the research will be used (Miles et al., 2020). All of the interviews took place remotely via Zoom in a password-protected meeting room. Participants were sent information regarding the Zoom meetings via email. Zoom was used so that interviews were able to be done remotely, also so that the researcher and participant could still meet face-to-face. This was important for the data analysis process because in the face-to-face meetings the researcher was able to detect emotion and tone through gestures and facial expressions (Estrada & Koolen, 2018; Evers, 2011). All interviews were recorded so that they could be transcribed for data collection and analysis in the software tool Nvivo (Estrada & Koolen, 2018). If a video interview could not take place within the timeline of the study, then a phone interview will be conducted instead.

The audio and video of the interviews were recorded so that the researcher could transcribe the interview and take notes on any non-verbal communication (Estrada & Koolen, 2018; Evers, 2011). Several measures were put in place to protect the confidentiality of the participants of the study. Researchers are responsible for removing identifiable data to protect people from harm, conflicts of interests, and misrepresentation (Sugiura et al., 2017). The recorded interviews were saved on the researcher's password-protected computer and in a password-protected folder. The program Nvivo was used as the primary tool for data collection and analysis. Audio-visual files uploaded in Nvivo were placed in the password-protected folder as well. All recordings and data sources were collected electronically so there was no need to account for any storage of tangible items. Upon conclusion of the study, the data was stored on a secure Boise State University server and will be kept there for the next five years in compliance with IRB regulations.

Data Analysis

The data analysis began as the data were collected. Beginning the analysis process during the data collection stage was helpful for reflection, for creating a structural unity, and for improving the reliability of the study (Elliot, 2018; Miles et al., 2020). The first analysis began with some organizational methods for keeping track of the data. The researcher created a table containing background information about the schools and the participants in the study. No names were used, but this table helped the researcher to organize the relevant information regarding the participants. A schedule of when and where the interviews were to take place was created in order to keep track of the procedures and to disclose how the study was being conducted to the teachers.

Once the first round of interviews was completed, the audio-visual files were loaded into Nvivo where they were transcribed and coded. This first round of the coding process was In Vivo coding which focused on what the participants were saying (Miles et al., 2020). In this method, the researcher focused on the words or phrases that were commonly used by the participants. After the initial round of coding was completed, the researcher performed a second round of coding. This second round of coding focused on organizing the data into patterns and themes, a method known as Pattern Coding (Miles et al., 2020). This step was an important process because it showed the bigger picture of the research and helped to focus the study on the analytic phase (Miles et al., 2020). Anney (2014) has supported coding the same item multiple times because it helps the researcher to gain a deeper understanding of data patterns.

In the coding phase of the study, the advisor of the researcher reviewed interview transcripts, enhancing the trustworthiness of the coding process. Both the researcher and advisor performed initial coding on the same interview transcripts independently from one another. They then met to compare, discuss, and determine a coding strategy for subsequent interviews. This process improved the credibility and trustworthiness of the study by having multiple researchers come to the same conclusions (Lincoln & Guba, 1985). Anney (2014) has suggested that researchers utilize support from other professionals who can provide academic guidance. He also has supported triangulation strategies that have multiple researchers examine the same artifact because it can “bring different perceptions of the inquiry and helps to strengthen the integrity of the findings” (p. 277).

Since there was a significant amount of data collected from the three interviews per participant, the analytic phase of the research was enhanced by data visualization. The next step for the researcher was to use methods of ordering to organize the data into tables and matrices. Matrices can be an effective way for researchers to look across cases, to deepen understanding, and to help make generalizations (Elo et al., 2014; Miles et al., 2020). For this study, a case-ordered descriptive meta-matrix was used to see the differences between the teachers and how they have used ALEKS in their classroom

(Miles et al., 2020). This matrix was created by using the queries feature in Nvivo, and it was organized by case and by the codings created from interviews.

The crosstab queries feature was used in Nvivo to show the strategies used and perceptions of teachers in each of the cases. One crosstab query organized the presence of a code related to the teaching strategies used by teachers. Similar queries were run to create tables for the presence of ease of use and usefulness codes for each teacher. By organizing the data in this manner, the researcher was able to find similarities and differences between the different cases (Elo et al., 2014; O'Cathain, Murphy, & Nicholl, 2010). These tables also assisted the researcher in determining gaps in the data collection. Doing this after each round of data collection helped to develop further questions for each subsequent round of interviews.

At the conclusion of the data organization, other methods of organizing information were used with the analysis phase. This was done by using tools for creating visual displays. Creating a visual display is helpful when connecting patterns, making inferences, and drawing conclusions (Verdinelli & Scagnoli, 2013). For this study, visual displays were put together after each round of data collection to assist with identifying themes, exploring questions, and making comparisons that improved future data collection (O'Cathain et al., 2010). Visual displays were created by the researcher that compared the teaching strategies used with ALEKS between all teachers, most teachers, and some of the teachers. A similar display was made for the teachers' statements regarding the ease of use and usefulness This process helped to generate meaning and confirm findings. Once the diagrams were made, the researcher sought out where the cases had similarities and differences. Miles et al. (2020) have suggested using a clustering method when looking for overlaps in the findings in order to draw conclusions. A visualization helped with, not only finding the overlaps between the data, but also with comparing and contrasting them as well.

Upon conclusion of the coding, organizing, and visualization stages, the researcher then began the process of drawing conclusions and establishing themes. A description of the findings from the study was written that addresses possible answers to the research questions. The researcher made generalizations about the key themes from this study and how they can be applied to other situations. The limitations of the study are stated and suggestions for future studies to be considered are included in Chapter 5.

Methodology Summary

This qualitative study used purposeful sampling to select for participation five high school teachers who have used ALEKS to teach mathematics. These teachers were asked to participate in three interviews with the researcher over the course of an academic school year. Multiple interviews were used as the data collection procedure and helped to establish a relationship between the researcher and the teachers (Knox & Burkard, 2009; Qu & Dumay, 2011). The time in-between interviews allowed the researcher to begin the data analysis phase and to make adjustments to the data collection process (Fossey et al., 2002; May, 1991). To enhance the trustworthiness of the study, interviews were coded multiple times with guidance from the researcher's advisor. The data was organized using matrices and analyzed using crosstab queries and visual displays in Nvivo. The researcher finalized the research process by drawing conclusions and writing them into a description of the findings.

Ethical Considerations

Since the interviews and observations took place via Zoom, it was important to follow proper procedures for the collection of data and for building trust with the teachers and schools involved. The first step in this process was to collect all of the permissions from the schools and teachers involved in the study. The intentions and procedures of the study were clearly stated to school administrators and participants. The participants and schools were asked to provide signatures on documentation verifying their agreement to participate in this study.

The research quality and trustworthiness was enhanced by many of the procedures followed by the researcher. The first of these was the involvement and input of the study participants from the outset. The researcher included the teachers in the process of approving the interview questions and shared with them the purpose and goals of the research study. This was an important step toward improving the validity of the study because it built trust with the participants (Creswell & Poth, 2018; Lincoln & Guba, 1985; Tracy, 2010). Although the interviews followed a semi-structured format where many of the questions were asked through conversation, teachers were made aware of the details of the interview procedure. Once the study was completed, the results were shared with the participants of the study in order for them to help judge its accuracy and credibility (Creswell & Poth, 2018). The researcher communicated with the teachers to make sure that their voice and message was accurately heard and described. Tracy (2010) has placed importance on informing the participants of the nature of the study and of the potential consequences of the research. Teachers were informed that this study will be used for publication in a research journal and in the dissertation.

At the beginning of the process and throughout the entire study, the researcher engaged in reflective writing in a research journal. This was an important process to follow because it assisted the researcher to determine understanding and to connect to biases, thoughts, and feelings (Anney, 2014; Watt, 2007). Other benefits of self-reflection can include the discovery of needed changes to research design, methods, and approaches (Orlipp, 2008). Writing reflections can help to reveal any biases that the researcher might have that could influence the interpretation of the study (Creswell & Poth, 2018). Since my study involved collecting data from participants multiple times, self-reflection was crucial to making sure the procedures were consistent and were amended if needed throughout the process.

Confidentiality is an important measure to consider when examining the quality of a study because it allows the participants to give unbiased responses and it protects their rights (Miles et al., 2020). The researcher assumed the responsibility of ensuring that measures were put in place to protect the identity of all participants (Legewie & Nassauer, 2018; Sugiura et al., 2017). To ensure confidentiality of the participants several precautions were implemented. The first of these was the assignment of an identification number to each of the schools and participating teachers. This was done in a password-protected document and on a password-protected computer. This was done to protect the identities of the individuals in the study, who may not be as honest without such assurances as confidentiality. During the interviews, any names of students or other school personnel mentioned by the participants were not used in the study. All of the recorded interview files also used an identification number and were saved on a password-protected computer.

Another ethical consideration was that the participants know that participation in the study neither impacted the learning of the students in the classroom nor affected their standing as a teacher within the school district. The data collection process did not interrupt the normal school day and interviews took place outside of the teachers' working hours. Qu and Dumay (2011) have stated that the general ethical principle for conducting interviews in qualitative research is to impose no harm. This study only asked for teachers to be honest about their experiences and perceptions and did not impose harmful consequences on participants.

Chapter 3 Summary

The purpose of this research study was to determine the teaching strategies teachers were using with ALEKS and what their perceptions were of its ease of use and usefulness. This study followed a qualitative design in order to allow for the participating teachers to share their experiences in their own words (Creswell & Creswell, 2018; Creswell & Poth, 2018; Fossey et al., 2002; Punch, 2013). A qualitative study was the chosen approach because the goal of the study was to gain meaningful insights from teachers' viewpoints and in their language (Creswell & Poth, 2018; Fossey et al., 2002; Siedman, 2006). In order to gain these insights, the researcher made use of three interviews spread throughout the course of an academic school year. Interviews were chosen as the sole source of data collection because they allowed for the researcher to engage in a conversational discussion intended to make the participants feel comfortable sharing sensitive details about their classroom practices (Fossey et al., 2002; Ryan et al., 2007).

A multi-interview format with three interviews was chosen so that the researcher and participants could develop a relationship and build trust with one another over time (Fossey et al., 2002; May, 1991). The interview procedures followed a three-interview format proposed by Siedman (2006). The first interview collected background information on the participants' use of ALEKS and on their perceptions of its ease of use and usefulness. The second interview collected data on the experiences and details of the teaching strategies the participants used with ALEKS in their classrooms. Finally, the third interview was more reflective and asked teachers for their perceptions of how they used the tool and for their perceptions of its ease of use and usefulness. Interviews were conducted in a semi-structured format to allow for the researcher to take a more conversational approach with participants (Fossey et al., 2002; Knox & Burkard, 2009; Qu & Dumay, 2011). This format also allowed for data to be analyzed after it was collected so that questions could be altered and themes could be addressed more thoroughly (Fossey et al., 2002; May, 1991; Qu & Dumay, 2011).

Five high school mathematics teachers participated in this study. The participants were selected using purposive sampling because certain criteria (in terms of their ALEKS use) must be met (Fossey et al., 2002). Measures were put into place to make sure that the teachers and schools had agreed to participate in this research study. The schools and teachers were informed of the requirements and purpose of the study and of the researcher’s intentions for its results (Creswell & Poth, 2018; Tracy, 2010). They were also informed of the measures taken to protect their confidentiality, and that the data collected in this study will be protected (Legewie & Nassauer, 2018; Sugiura et al., 2017).

The data was collected through interviews performed remotely. The interviews were recorded and transcribed so that rounds of coding were able to be performed. The first round of coding was In Vivo coding, focused on what the participant was saying and organized by key words and phrases (Miles et al., 2020). This was followed by a second round of coding where the researcher explored patterns and themes in the data (Miles et al., 2020). The data was then organized into matrices and visual displays in order to identify and organize the themes and similarities/differences between the participants' responses (O'Cathain et al., 2010; Miles et al., 2020; Verdinelli & Scagnoli, 2013). These themes were written into a narrative that addressed the research questions of the study. This process of data analysis took place after each round of interviews so that the researcher was able to reflect and make adjustments to future interview questions and procedures (Fossey et al., 2002; May, 1991). Teachers participated in the final step of data analysis by making sure that their experiences and their words were accurately represented in the conclusions of the study (Creswell & Creswell, 2018).

CHAPTER 4: FINDINGS

Introduction

The goal of this study was to understand the teaching strategies used by high school mathematics teachers (who use ALEKS in their mathematics classes) and to analyze those teachers' perceptions of ALEKS's ease of use and usefulness. A basic qualitative design was used for this study in order to directly hear from teachers about their experiences, teaching methods, and perceptions of using ALEKS. TAM, which suggests that the ease of use and usefulness of a tool influences the acceptance and use of a technology tool, served as the framework for this study (Davis, 1989). In this study, five high school mathematics teachers were interviewed three times throughout a school year, and their responses were analyzed to answer the following research questions:

1) What teaching strategies are high school mathematics teachers implementing while using the adaptive learning tool, ALEKS?
2) How do high school mathematics teachers perceive the ease of use of the adaptive learning tool ALEKS in their classrooms/classes?
3) What are high school mathematics teachers' perceptions of the usefulness of the adaptive learning tool, ALEKS in high school mathematics classes?

This study helps to fill gaps in the research related to adaptive learning tools because it collected information about using ALEKS from actual teachers in their own voices. This was a significant gap in the literature related to using adaptive learning tools in a mathematics classroom. Several studies have investigated effective teaching practices for mathematics instruction (Anthony & Walshaw, 2009; Bartell et al., 2017; Caro et al., 2016; Hattie & Timperley, 2007; NCTM, 2020c; Shute, 2008). There has also been extensive research conducted on the role technology plays in mathematical instruction (Sen & Ay, 2017; Wachira & Keengwe, 2011). However, very little research has been conducted involving how adaptive learning tools are used by teachers, nor is there any research that attempts to analyze those teachers' perceptions of its usefulness in teaching. ALEKS is an adaptive learning tool that is used by hundreds of thousands of high school students each year (ALEKS, 2020b). This study helps to fill gaps in the literature by investigating the use of ALEKS in the classroom. It accomplishes this by examining the experiences and perceptions of teachers using ALEKS throughout a school year.

Methodology

The research questions asked in this study inquire into the teaching strategies used with ALEKS by teachers and those teachers' perceptions of ALEKS's ease of use and usefulness. In order to address questions of this study, a qualitative methodology was selected in order to gain an understanding of the experiences and perceptions of teachers who use ALEKS in high school mathematics classrooms. This study followed a basic qualitative design, utilizing purposeful sampling, data collection through interviews, and data analysis that generated the themes needed to answer the research questions. This section describes the background information of the participants in the study, the data collection process, and the data analysis procedures.

The researcher used interviews to collect qualitative data about the actions and perceptions of teachers using ALEKS in high school-level mathematics classrooms. Teachers were asked to participate in three open-ended interviews during the course of one academic school year. The interviews ranged from 20 to 30 minutes and took place via Zoom. Interviews were selected as the primary source of data collection because they allowed teachers to share their experiences in their own voice and encouraged teachers to open up and share details of their use and opinions of ALEKS (Fossey et al., 2002; Ryan et al., 2007; Seidman, 2006). A three interview format allowed for the researcher to build a relationship with the participants and to allow for a more conversational approach to be taken (Knox & Burkard, 2009; Qu & Dumay, 2011).

The data analysis process began as soon as the data was collected, with the audio-visual files being transcribed into text via the computer program Nvivo. The researcher used Nvivo to conduct multiple rounds of coding to identify what the participants were saying in the interviews and to organize the data into themes and categories. Following the coding procedures, data was organized into tables by using the crosstab queries feature in Nvivo. The data was sorted into several tables and visualizations to find similarities and differences between participants' responses to various questions. Visual displays were created to determine patterns and themes across participants and interview rounds. After the data analysis was completed, the researcher drew several conclusions and identified themes in order to answer the research questions.

Participants

Participants for the study were selected using purposeful sampling to ensure that they met the specific parameters of the research topic. Emails were sent to school administrators across the Chicagoland area seeking volunteers to participate in the study. Potential candidates were screened by the researcher to determine whether they met the criteria of the study and to inform them of the requirements, procedures, and purpose of the study. Participants for this study needed to be high school mathematics teachers who had at least two years of teaching experience, who had at least one year of experience using ALEKS, and who planned on using the tool as part of their core curriculum. Of the potential candidates, five teachers were chosen to take part in the research. The five teachers selected were all high school-level mathematics teachers who used ALEKS as a source of curriculum in their classrooms. Background information on the teachers, on the classes they teach, and on their experience with ALEKS is displayed in Table 4.1

Table 4.1 Background Information of Participants.

Participant Pseudonym	**Grade Level Taught**	**Course Taught with ALEKS**	**Years of Teaching Experience**	**Years of Experience With ALEKS**	**Training with ALEKS**
Steve (Participant 1)	Freshman	Math II Honors	18 Years	4 Years	Some Formal Training
Tony (Participant 2)	Seniors	College Algebra	23 Years	2 Years	No Official Training, Self-Taught, Help from Colleagues
Bruce (Participant 3)	Seniors	Transitional Math & Statistics	35 Years	4 Years	Help from Local Community College and Colleagues
Natasha (Participant 4)	Sophomores - Seniors	Honors Pre-Calculus	15 Years	2 Years	Help from Local Community College and Colleagues
Donald (Participant 5)	Algebra II	Juniors & Seniors	12 Years	3 Years	Self-Taught

Steve

Steve has been a high school mathematics teacher for 18 years and has also been the mathematics department head for his high school. He used ALEKS this school year in his Freshman Math II Honors class. Although he has used ALEKS for four years, this was the first time using the tool with Freshmen. At his school, the product was typically used for seniors who had struggled with mathematics in the past. He described his training with ALEKS as having occurred through some formal workshops with the teachers in his school, but also stated that he also learned how to use it by spending time working with the tools. Steve made the decision to use the ALEKS product because he felt that it offered the ability to give reliable assessments. He stated that "security was a big concern" and that ALEKS "pretty much guarantees that not every student will have the exact same question." He also supported using ALEKS due to the built-in differentiation that it provides and because students would be able to advance through more curriculum with it. This was especially concerning to him given that the majority of his lessons were conducted remotely and that he only saw his students every other day. Steve's school was fully remote during the course of this study. In the class he used ALEKS in, he saw the students for 185 remote minutes per week which was 45 minutes fewer minutes per week than he had seen them in previous school years.

Tony

Tony had no official training with ALEKS and learned to use its features by working with colleagues at his school. He used ALEKS for the first time during the year before the study in his senior-level math class, and prior to that he had some experience with the tool. He has been a high school math teacher for 23 years. During this study, he used ALEKS in a College Algebra class with seniors who have traditionally struggled in their math classes. His school was in a hybrid format for the school year, and he saw his students for 60 minutes per week in person and 85 minutes per week remotely. His rationale for using ALEKS was that he hoped to address a wide range of abilities and to measure student growth throughout the school year. He felt that ALEKS had tools that would allow him to do that.

Bruce

Bruce has taught high school mathematics for 35 years. He has had four years of experience using ALEKS before participating in the study. All of this experience with ALEKS has been with seniors in a class called Transitional Math: Quantitative Literacy & Statistics. The class is designed for college-bound seniors. He started using ALEKS in order to meet the credit requirements of the local community college, which was also using the tool. During the course of this study, he was using ALEKS for the Quantitative Literacy & Statistics class. His school had only remote classes, and he would meet with students via Zoom for 165 minutes per week. On Mondays, he would meet with all of the students for 25 minutes, and then he would see the students on alternating days for 60 minutes. He was also able to meet with students if they signed up for office hours, which ran for 45-90 minutes per day. Bruce learned how to use ALEKS by receiving brief tutorials from staff members at the local community college and by receiving help from his colleagues.

Natasha

Natasha has used ALEKS for two years. She elected not to receive formal training on the tool, but received help on how to use it from the local community college she is working with. Natasha used ALEKS during the previous year's in-person instruction. During the year of this study, she used ALEKS in a remote-only setting where she sees her students every other day for 60 minutes and then for 25 minutes one day per week as well. Natasha has been a mathematics teacher for 15 years. During this year, she taught Honors Precalculus with ALEKS, a class that has sophomores, juniors, and seniors in it. Natasha's rationale for using ALEKS was that it could provide more support and differentiation for students. This was especially important for her given that she would only see students for a limited amount of time per week compared to prior years.

Donald

Donald has been a mathematics teacher for 12 years and has used ALEKS for the past three years. Donald received no training on ALEKS. He piloted the program for his school and taught himself how to use it. During the time of this study, Donald used ALEKS in an Algebra II class composed of juniors and seniors, a high number of whom had Individualized Education Plans (IEPs) and 504 Plans. For this study, he taught in a hybrid setting where he worked with students remotely for 85 minutes per week and in person for one sixty minute period per week. Donald wanted to use ALEKS for its ability to deliver differentiated content, its ability to provide explanations for students, and for the built-in tools like the graphing calculator. He also wanted to use ALEKS because of the hybrid model his school was operating under; he felt it was a tool that would work well in-person and also virtually.

Data Collection

The primary source of data was individual semi-structured interviews. Interview questions were prepared and shared with teachers in advance of the interview, but follow up questions were also asked to provide clarification and further details. Interviews were conducted in this format in order to better explore themes, to allow for flexibility in questions, and to keep the interviews conversational (Fossey et al., 2002; Knox & Burkard, 2009; Qu & Dumay, 2011). Since this study asked participants to share details of their classroom, a semi-structured interview format was chosen so that teachers felt comfortable providing information about their experiences.

Teachers were asked to participate in three interviews throughout the school year. A multi-interview approach was chosen to develop a deep understanding of the participants' teaching situations and perspectives on the phenomenon being studied, the use and usefulness of ALEKS. It was also chosen so that the researcher could build a relationship with the participants and foster trust. Prior to each interview, teachers were emailed a document outlining the questions that would be asked during each round. In between rounds of interviews, the researcher coded and analyzed the data, making adjustments to questions based on themes drawn from the interviews. The multi-interview format also allowed the researcher to analyze individual responses so that additional questions could be asked or clarification could be provided.

Prior to the first interview, teachers met with the researcher to discuss the parameters of the study and its intentions. In accordance with the IRB, participants were informed of the goals of the study, of their rights, and of how the research will be used. All interviews were conducted remotely in a password-protected Zoom meeting room.

The video and audio from the Zoom sessions was recorded and later transcribed to text. The transcriptions were imported into Nvivo for data analysis. All identifiable information about participants was removed and all of the files were stored on a password-protected computer and in a password-protected folder. The data was also stored on a secure server provided by Boise State University where it will be kept for five years.

The first interview took place within the first month of the school year, and one purpose of this interview was to build rapport between participants and the researcher. Another purpose was to collect background information relevant to their teaching experiences with ALEKS and their plans for using the tool during the coming school year. Teachers were asked to share their experiences and perceptions of ALEKS prior to the beginning of the school year. Teachers were asked questions about their perceptions of how useful and easy to use ALEKS would be. Appendix A displays the outline of questions that teachers were asked during the interviews. Due to the semi-structured format selected for the interviews, not all questions were asked to every teacher because some teachers addressed questions during other responses. In addition, some teachers were asked follow-up questions or for clarification based on their responses.

The second round of interviews took place six-to-seven weeks after the first interviews were concluded. The purpose of the second interview was to collect information about the teachers' experiences using ALEKS during the 2020-21 academic year. The outline of interview questions is listed in Appendix B. These questions varied a little bit from participant to participant depending on their responses to previous interview questions, the results of the data analysis, and whether additional clarification was needed. These interview questions asked teachers to share the specific ways that they used ALEKS in their daily tasks for instruction, assessment, data analysis, feedback, and personalization. In this round, teachers were also asked to share their perceptions of how easy to use and useful ALEKS had been for their teaching during that academic year. Upon conclusion of the second round of interviews, the researcher again analyzed the data and made adjustments to themes and questions for future interviews.

The final round of interviews took place another six-to-seven weeks after the previous round. The purpose of this interview was to allow teachers to reflect on their use of ALEKS and to consider the meaning of their experiences. It also allowed the researcher to gain clarity about specific aspects of the teachers' experiences. The outline for this interview is shown in Appendix C. In this round of interviews, teachers were asked to reflect on their teaching experiences using ALEKS and on their perceptions of its effectiveness. They were also asked to reflect on the fact that all of the teachers were in a remote learning setting during the time of the study and on how they might use ALEKS in the future based on these experiences. This round of interviews asked the teachers to share their overall perceptions of the ease of use and usefulness of ALEKS.

To summarize, the data collection procedure for this study followed a semi-structured interview format in which teachers were interviewed three times throughout the school year. This format was chosen for this study so that a relationship could be established between the researcher and the participants. It also allowed for the researcher to be more flexible about the questions being asked, allowing the interviews to be more conversational. The first interview collected background information about the participants, their expectations of how they planned on using ALEKS this year, and their perceptions of ALEKS's ease of use and usefulness. The second interview focused on how each participant used ALEKS (specifically for teaching), and their perceptions of its use. The final interview asked teachers to reflect and provided clarification on the research questions. In between interviews, data was analyzed and adjustments/additions were made to the interview outlines. Individual questions were added for teachers based on the need for additional information or clarification. All of the interviews were conducted and recorded via Zoom, transcribed to text, and imported into Nvivo for data analysis.

Data Analysis

The data analysis process began after the first round of interviews and continued after each subsequent interview. The interviews were transcribed into text, imported into Nvivo, and underwent the first round of coding. The first round of coding used In Vivo coding which focused on the words and phrases participants used in the interviews. These words and phrases were coded into nodes based on what the teachers were saying. A second round of coding followed in which the researcher organized the nodes into patterns and themes. The data was coded multiple times to make sure the researcher was able to gain a deeper understanding of the patterns and themes. This multi-coding process was done after each round of interviews. In order to improve the credibility and trustworthiness of the study, the advisor of the researcher independently coded the first round of interviews, met with the researcher to compare codings, and discussed future coding strategies (Anney, 2014; Lincoln & Guba, 1985).

Table 4.2 below displays the nodes that were coded for each theme related to the teaching strategies used by teachers. This table also provides descriptions of each code that was used and sample quotes from teachers. Table 4.3 also displays the codes, descriptions, and sample quotes that were used when coding themes related to the ease of use of ALEKS. Finally, Table 4.4 displays a table with the codes, descriptions, and sample quotes that were used in coding themes related to the usefulness of ALEKS. Each of these tables displays the codes and descriptions that were used after the final round of interviews. The quotes used in these tables were taken from all rounds of interviews.

Table 4.2 Coding Description of Teaching Strategies Used with ALEKS

Code	Coding Description	Coded Quotes
Assessment & Grading	Types of assessments teachers used in ALEKS, how they used them, and if they factored it into the students grade	"like a 30 question test so I have my students also take the assessments for each chapter" (Bruce) "Assessments are the same as assignments but it is more time bound and they don't get have access to as many other things like they didn't maybe only get one chance instead of many chances" (Donald)
Data Analysis	The ways that teachers use ALEKS tools to analyze student success, progress, and determine future lesson planning	"I'm using the detail question report prior to class to have a one or two questions that I get to go over at the start" (Steve) "I can go and see their pie chart you know topics that they've mastered and topics that they haven't and I can suggest couple topics" (Tony)
Feedback	How teachers use the feedback provided through ALEKS and ways in which they use ALEKS to give feedback to students	"Immediate response immediate feedback on how they're doing with the with the objectives" (Natasha) "My path is a good way to provide feedback on their goal setting but then also like providing feedback to them like content specific feedback" (Bruce)

Code	**Coding Description**	**Coded Quotes**
Goal Setting	The expectations of what students are required to complete on ALEKS and how teachers communicate learning goals with students on ALEKS	“Basically I was going to have weekly objectives goals for them to work on” (Steve) “How we look at different percentages for mastery within those to help them move along to the my path” (Bruce)
Individualized Pathway	The use of the ALEKS My Path by teachers or descriptions of how teachers provide personalization for students	“I have a students use their learning path so I follow up with a weekly goal of topics on their learning path” (Donald) “I had to basically used it as a you know like an understanding vehicle for students to continue on their path to work with the weaknesses” (Bruce)
Initial Assessment	Use of the initial assessment in ALEKS, rationale for why they used it, and how they used the assessment	“The first thing we did was we took our first placement assessment the first couple days in class that gave me an idea of where all my 17 kids were at and look at their work and it helped me plan” (Tony) “Just to see where they are in that initial pie chart is a nice thing to kind of gauge how are the students dancing in a quick sense” (Bruce)

Code	Coding Description	Coded Quotes
Instruction of ALEKS Examples	Description of how teachers used ALEKS during class time, either remotely or in-person	"I start the class with that from there and then I will go over the problem together and I can use like a student view so kind of show them how to use the tools you when I'm done with work on the problem" (Natasha) "Used it as a warm-up or as a exit slip for a real time understanding of what their students know" (Steve)
Practice of In-Class Objective	The assignments teachers provide for students in ALEKS that align with the lessons delivered by teachers during class time	"Currently, for example, we are doing probability and so I have four assignments in ALEKS that is divided up those those skills and students work on those assignments" (Donald) "Homework assignments that based on the objective or a lesson" (Natasha)

Table 4.3 Coding Description of Ease of Use of ALEKS

Code	**Coding Description**	**Coded Quote**
Easy to Use	Descriptions of if and how ALEKS was easy for them to use as well as examples of why it is easy for them to use	"I thought it would be user-friendly and after using it I found it to be even better than I expected" (Steve) "It is pretty easy. It is very, very easy to use, you can get all sorts of reports on you want and you have the information about the entire class" (Natasha)
Initial Struggles	Descriptions on some of the struggles teachers had using ALEKS	"I had some trouble navigating and kind of understanding that at the beginning" (Bruce) "I would not say it very intuitive" (Donald)
Limitations	Limitations on what teachers weren't about to do in ALEKS	"Just like troubles with some of the toolbars that show up in an iPad" (Bruce) "It'd be great if teachers could have a little bit more control to be like to make sure that students can get into the assignments that you want" (Donald)
Needed Time	Commentary from teachers on how they needed time to learn ALEKS	"It's a matter of time for me and like how much time I have to get in there" (Tony) "It just sometimes tedious isn't it just takes some time to sort through" (Steve)

Table 4.4 Coding Description of Usefulness of ALEKS

Code	Coding Description	Coded Quote
ALEKS Instructional Tools	The ways in which teachers found specific tools in ALEKS to be useful	"Great job of asking questions that show conceptual understanding" (Steve) "Accessibility is very useful and powerful as a teacher" (Donald)
Assessment Tools	Description of what teachers found useful about the assessment tools in ALEKS	"I like the possibility for students to access any helps with ALEKS throughout the assessment" (Natasha) "Is really helpful that students can all have different questions I feel that that minimizes copying and minimizes cheating and really gets that what he seems know" (Donald)
Differentiation	Teachers' comments about the usefulness of ALEKS to help them provide differentiation for students	"I really liked from the homework perspective is the differentiation" (Steve) "Students can do their work and also get explanations via ALEKS to differentiate their learning" (Donald)

Code	Coding Description	Coded Quote
Feedback	The ways in which the feedback given in ALEKS is useful for students	“Timely feedback to the student. I think it's very specific for students because students don't know how to self diagnose a lot of their mechanical errors” (Steve) “Helping students kind of like get a quicker feedback on things I think that you know that it really helps out a lot” (Bruce)
Negative Perceptions	Feedback from teachers on the ways in which ALEKS was not useful	“ALEKS from a teacher’s standpoint lacks a little bit because I can’t see those things. It's not specific enough that I can go and diagnose the specific issue.” (Steve) “they got the questions right but it was in the wrong form so they didn't necessarily read that wonderful little italics or small print” (Bruce)
Personalization	Descriptions of how teachers used ALEKS to personalize instruction and rationale for why it was useful for them	“It's really useful so I started creating a assignments just tailored for the specific students” (Natasha) “Because it really kind of go after the knowledge check gets their gaps and some of the things that they really need to work on” (Tony)

Code	**Coding Description**	**Coded Quote**
Question Generation	How the ability for ALEKS to generate multiple practice problems for students is useful for teachers	"really good because of the way it generates multiple problems, examples, and allows for students to kind of fail into success" (Steve) "I really like that that regeneration" (Bruce)
Remote Learning Usefulness	Due to COVID-19, teachers needed to teach remotely so these codes are what makes ALEKS useful in remote teaching	"ALEKS has been very helpful especially in this time of remote learning to have a resource that can to do as much as ALEKS does" (Donald) "Because of remote learning and it's a good tool for formative because it gives students feedback right away so they don't have a teacher necessarily with them and it allows them to practice anytime" (Natasha)
Saving Time	Descriptions of how features in ALEKS helped teachers to be more efficient in planning lessons	"In one respect it allows me to minimize time on remediation and maximize time on new instruction." (Steve) "Just efficiency with creating things like that. I mean it it does it" (Tony)

Upon completion of each coding session, the data was then organized into tables in order to compare and contrast codes among participants, deepen understanding of the themes of the interviews, and draw conclusions. The crosstab queries feature in Nvivo was used to determine the strategies used with ALEKS by the participants as well as their perceptions of its usefulness. Figure 4.1 and Figure 4.2 display the crosstab queries that were utilized for the codings related to the strategies used with ALEKS after the first and second round of interviews. Some of the codings were changed and moved based on answers from teachers during the second round of interviews. A crosstab query was not created after the third round of interviews because teachers did not share any new teaching strategies during that interview. Figures 4.3, 4.4, and 4.5 display the codings of teachers' responses about the ease of use of ALEKS from interviews one through three. Some of the codings were changed and moved based on teachers' answers in interviews two and three. These queries display the presence of individual codes in the responses of each of the participants from interview to interview. Figures 4.6, 4.7, and 4.8 display the presence of individual codings based on the teachers' descriptions of the usefulness of ALEKS from interview one to interview three. Additional codes were added and changed based on answers from teachers in interviews two and three. These visualizations allowed the researcher to determine what adjustments and additions needed to be made in future interviews, to determine questions for specific teachers, and to help the researcher create organization tables in the next phase of the data analysis process.

How ALEKS is Used

Nodes	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
Assessment & Grading	Yes	Yes	Yes	Yes	No
Asynchronous Learning	Yes	Yes	Yes	Yes	Yes
Data Analysis	No	Yes	No	Yes	Yes
Feedback	Yes	No	No	Yes	No
Goal Setting	Yes	Yes	Yes	No	Yes
Individualized Pathway	Yes	Yes	No	No	Yes
Initial Assessment	No	Yes	Yes	Yes	No
Intruction of ALEKS Examples	Yes	Yes	Yes	Yes	Yes
Practice of In Class Objectives	Yes	No	No	Yes	Yes

Figure 4.1 Teaching Strategies Used with ALEKS (Round 1 Interviews)

Nodes	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
Assessment & Grading	Yes	Yes	Yes	Yes	Yes
Data Analysis	Yes	Yes	Yes	Yes	Yes
Feedback	Yes	Yes	Yes	Yes	Yes
Goal Setting	Yes	Yes	Yes	Yes	Yes
Individualized Pathway	Yes	Yes	Yes	Yes	Yes
Initial Assessment	Yes	Yes	Yes	Yes	Yes
Intruction of ALEKS Examples	Yes	Yes	Yes	Yes	Yes
Practice of In Class Objectives	Yes	Yes	Yes	Yes	Yes

Figure 4.2 Teaching Strategies Used with ALEKS (Round 2 Interviews)

Nodes	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
Easy to Use	Yes	Yes	Yes	Yes	No
Initial Struggles	No	No	Yes	No	Yes
Needed Time	No	Yes	Yes	No	No
User-Friendly	Yes	Yes	Yes	Yes	No

Figure 4.3 Ease of Use of ALEKS (Round 1 Interviews)

Nodes	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
Easy to Use	Yes	Yes	Yes	Yes	Yes
Initial Struggles	Yes	No	Yes	No	Yes
Limitations	Yes	Yes	Yes	No	No
Needed Time	Yes	Yes	Yes	No	Yes

Figure 4.4 Ease of Use of ALEKS (Round 2 Interviews)

Nodes	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
Easy to Use	Yes	Yes	Yes	Yes	Yes
Initial Struggles	Yes	Yes	Yes	No	Yes
Limitations	Yes	Yes	Yes	No	Yes
Needed Time	Yes	Yes	Yes	No	Yes

Figure 4.5 Ease of Use of ALEKS (Round 3 Interviews)

Nodes	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
Assessment Tools	Yes	Yes	Yes	Yes	No
Differentiation	Yes	No	No	Yes	No
Negative Perceptions	No	Yes	Yes	Yes	No
Personalization	Yes	No	No	Yes	Yes
Remote Learning Usefulness	Yes	Yes	Yes	Yes	Yes

Figure 4.6 Usefulness of ALEKS (Round 1 Interviews)

Nodes	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
ALEKS Instructional Tools	Yes	Yes	No	Yes	Yes
Assessment Tools	Yes	Yes	Yes	Yes	Yes
Differentiation	Yes	Yes	Yes	Yes	Yes
Feedback	Yes	Yes	Yes	Yes	Yes
Negative Perceptions	Yes	Yes	Yes	Yes	No
Personalization	Yes	Yes	Yes	Yes	Yes
Question Generation	Yes	Yes	No	No	Yes
Remote Learning Usefulness	Yes	Yes	Yes	Yes	Yes
Saving Time	Yes	No	No	Yes	No

Figure 4.7 Usefulness of ALEKS (Round 2 Interviews)

Nodes	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
ALEKS Instructional Tools	Yes	Yes	Yes	Yes	Yes
Assessment Tools	Yes	Yes	Yes	Yes	Yes
Differentiation	Yes	Yes	Yes	Yes	Yes
Feedback	Yes	Yes	Yes	Yes	Yes
Negative Perceptions	Yes	Yes	Yes	Yes	Yes
Personalization	Yes	Yes	Yes	Yes	Yes
Question Generation	Yes	Yes	Yes	No	Yes
Remote Learning Usefulness	Yes	Yes	Yes	Yes	Yes
Saving Time	Yes	Yes	No	Yes	No

Figure 4.8 Usefulness of ALEKS (Round 3 Interviews)

In order to gain a better understanding of the interview responses and to find similarities and differences in the data, several tables were made based on the codings and crosstab queries. The tables displayed in Appendix D show a comparison (among participants) of the teaching strategies used with ALEKS. The purpose of this table was to organize the data into themes so that the researcher could determine the ways in which ALEKS was used by teachers and also to see how its use varied between them. Appendix E displays the table used to analyze questions related to the ease of use of ALEKS among the participants. Appendix F displays the ways that teachers perceived

ALEKS to be useful in their teaching. All of these tables were adapted after each round of interviews as participants provided additional information and/or clarification on their use and perceptions. These tables were used by the researcher to adapt interview outlines throughout the data collection process as well. The final interview asked teachers to reflect on their use of ALEKS and to describe the ways they might use ALEKS in the future based on their experiences this past school year. Appendix G displays a table showing the responses among interview participants.

Upon conclusion of the data organization, visual displays were created to make connections between patterns, to compare the similarities and differences among teachers, and to draw overall conclusions. Visual displays were made after the second round of interviews and were adapted after each subsequent round based on the interview responses, coding procedures, and data organization. These displays helped the researcher to find overlaps in the data, explore questions to ask in future interviews, and determine themes. Figure 4.9 shows a visual display of how the teachers use ALEKS broken down into strategies that all teachers use, most teachers use, and some teachers use. This figure displays teaching strategies that were prevalent throughout all of the teachers as well as some strategies that only a few teachers utilized. This visualization helped the researcher to determine overall themes throughout the interviews and similarities and differences among the teachers. Figure 4.10 is a similar visual display, but displays the ways in which teachers perceive ALEKS to be easy to use and useful in their teaching. This display also helped the researcher to find similarities and differences between how teachers perceived ALEKS to be easy to use and useful. Figures 4.9 and

4.10 helped the researcher to determine themes that were consistent across all of the teachers versus what was specific to just certain teachers.

Figure 4.9 Visual Display of Teaching Strategies Used with ALEKS

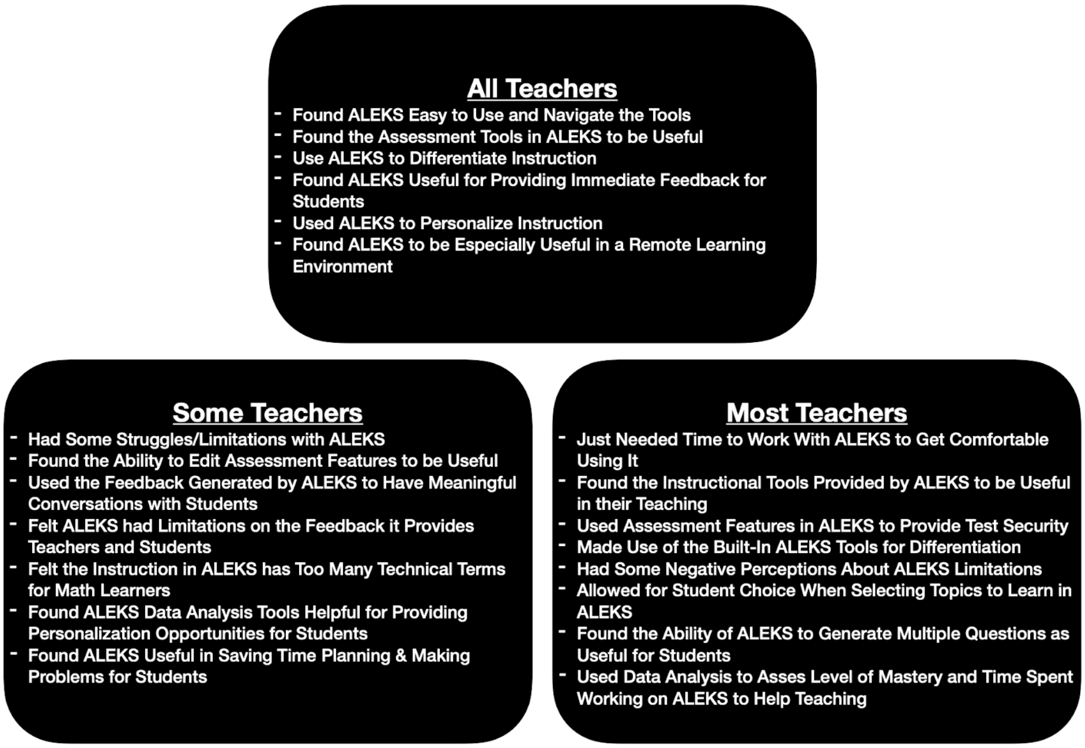


Figure 4.10 Visual Display of the Ease of Use and Usefulness of ALEKS

In the data-analysis stage of this study, the researcher coded the data multiple times. The first round used In Vivo coding to focus on what the participants were saying, and the second round used Pattern coding to organize the coding nodes into patterns and themes based on the research questions (Miles et al., 2020). To improve the credibility and trustworthiness of the data, the researcher's advisor independently coded the round one transcripts and met with the researcher to compare codings and discuss future strategies. Data was then organized into several tables that the researcher used to develop themes and conclusions, find similarities and differences between participants, and make adjustments to interview outlines. Coding procedures and data organization strategies were conducted after each round of interviews. In the final stage of analysis, data visualizations were created to establish overall themes and make connections between participants.

Findings

In this section, the research findings are discussed. This section is divided into one section for each research question and then subdivided by the themes that were established within each of the questions.

Research Question 1

Research Question 1: What teaching strategies are high school mathematics teachers implementing while using the adaptive learning tool, ALEKS?

In order to answer this question, the data from the interviews underwent multiple rounds of coding and was then organized into a table that compares the ways that teachers use ALEKS. These tables are displayed in Appendix D and Appendix G. There were several themes that came out of the data analysis which are discussed in this section. These themes all contribute to answering this research question. The themes associated with strategies used with ALEKS were: (1) Assessment, (2) Data Analysis, (3) Practice of Learning Objectives, (4) Individual Pathways, and (5) Future ALEKS Use. These themes were based on the codings presented previously in Table 4.2.

Theme 1: Assessment

The most common way that teachers used ALEKS was to assess the learning objectives that were taught in class. Almost every teacher interviewed stated that they used the assessments built into ALEKS. In interview two, Bruce explained that he used ALEKS for "like a 30 question test for each chapter." Although all of the teachers used some form of assessment tool in ALEKS, several of them supplemented their assessments with additional tasks. Referring to how he supplemented tasks with ALEKS, Donald stated in the second interview that he used "a video explanation of their topic with a rubric that I use that kind of gives them feedback on how well they are explaining the topic that they're learning in ALEKS." Tony also required students to provide additional items with their assessments in order to check their work:

> I have the student take a picture of their work I required them to do. I would then go into the ALEKS and check to make sure that their time or their topics that they said they completed were actually completed, and I would give them a score.

Many of the teachers in this study used ALEKS to assess students on the objectives that were taught during either in-person or remote class time. Some of the teachers required students to supplement their assessments with additional explanations and/or examples of their work.

Theme 2: Data Analysis

All of the teachers interviewed mentioned that they used the data analysis tools provided by ALEKS to follow student progress toward the learning objectives. Many of them used it as a way to assess student growth and progress as students worked through the individualized pathway (referred to as the ALEKS My Path) that ALEKS provides. Tony used ALEKS mostly for the individualized pathway and in the second interview described using the ALEKS data analysis tools in the following way:

> This past week we just gave our second placement test, and what I want to see from the kids is some growth with one score to the next. I can go and see their pie chart. You know topics that they've mastered and topics that they haven't, and I can suggest a couple of topics. I can actually go in and see the number of

> attempts, where kids are struggling, the ones they're skipping, and the ones they're missing for one reason or another.

All of the teachers also used ALEKS to identify student struggles and to assist them with lesson planning. Teachers did this at the macro level by looking at classwide struggles. For example, Steve, who uses ALEKS for students to practice objectives that were taught in class, stated in the second interview: "I'm using the detailed question report prior to class to have one or two questions that I go over at the start of class." Natasha commented in interview three that she also used the data-analysis tools in ALEKS to identify classwide successes or struggles:

> I also monitor their formative results to see if they are ready, if we need to maybe review anything in class together. I am using a lot of collected data of which of the objectives they are working on and how fast they move through the course of those problems.

Some teachers used ALEKS to identify the struggles or progress of individual students by checking their pie chart on ALEKS or the "time on" graph. Donald mentioned checking individual progress during the third interview, stating that "I definitely am always checking that data. If they're not turning the assignment in or not getting good scores, I follow up with the students individually."

Theme 3: Feedback

Several of the teachers stated that they relied on the feedback given through ALEKS when students are working independently. Many participants gave feedback to students based on information they collected from the ALEKS data analysis tools. Some of the feedback they gave was based on specific math topics. For example, Donald stated that: “when I see that students are not doing well on a particular assignment, that's when I maybe need to make out an additional lesson or make an additional video to give them feedback.” Additionally, some teachers gave feedback to students about their individualized progress by having discussions with them or engaging in goal setting. Bruce, for instance, reflecting on his use of ALEKS to have conversations with students, stated in the third interview that:

> The ALEKS My Path is a good way to provide feedback on their goal setting but then also like providing content specific feedback. We also get a lot of good reflection -good math reflection - that we can talk about, and they can also be proactive, which is another cool element.

All of the teachers mentioned using ALEKS for instruction and for giving feedback during class time. Many of the teachers used ALEKS during class time to do bell ringers and warm-ups, described by teachers in this study as a set of problems for students to complete at the beginning of class. These exercises were typically related to the lessons taught in class, created to address student misconceptions, or given to provide feedback to students. Almost all of the teachers mentioned bringing up ALEKS on their computer screens during remote-learning sessions in order to give feedback about how to use the tool or to correct specific errors being made by students. Some of the teachers had the students work on ALEKS during class time and gave live feedback to them as they were working. Donald, discussing his use of ALEKS during the second interview stated: “I can give them individual support and help during the instruction. They get real-time feedback in either audio, text, or video. Whatever they need.”

Theme 4: Practice of Learning Objectives from Class

Many teachers assigned a weekly goal for in-class objective completion based on what was taught during the week. These goals related to units being taught in class. Some teachers also had weekly goals for the students in the ALEKS My Path. These teachers expected students to complete a certain percentage of work, spend a certain amount of time, or cover a certain number of topics per week or per semester. Some teachers assigned the My Path but without specific goals for student completion. In the first interview, Steve outlined how he planned to use ALEKS over the course of the year:

> Basically, I was going to have weekly objective goals for them to work on, consistently ten topics a week. I use twelve basic problems, and then I give them three attempts per question and unlimited attempts at the assignment. My thoughts being that: for those who need additional work ALEKS provides it because it will regenerate a new question.

The teachers all had different expectations for students in terms of practice. Tony stated that he wanted students to "use it a minimum of an hour a week" while Donald set objective-based goals in which the students complete "24 assignments that range from six to twelve questions each." Several of the teachers combined using the individual pathway for students to work on during asynchronous learning time or homework with giving assignments related to the course itself.

Theme 5: Individual Pathway

The individualized pathway that ALEKS provides allowed for students to progress at their own pace while the teachers were able to monitor their progress.

ALEKS also offers an initial assessment that collects information from students and uses their algorithm to create an individualized pathway for students to learn through the program. All of the teachers in this study mentioned using the initial assessment tool in ALEKS to get a baseline of what their students knew and didn't know. In reference to using an initial assessment in interview two, Tony stated:

> My plan was to use ALEKS first of all to get a baseline of the kids skills. The first thing we did was: we took our first placement assessment the first couple days in class that gave me an idea of where all my 17 kids were at and look at their work, and it helped me plan.

After the initial assessment, teachers used the ALEKS My Path in different ways. Some of the teachers, Tony and Donald in particular, used it as a significant part of their class. Tony assigned students a set number of minutes for students to spend on it per week while Donald required students to complete a set number of objectives each week. Natasha and Steve, on the other hand, viewed the individualized pathway in ALEKS as optional. All of the teachers in the study offered opportunities for students to use the individualized learning but to varying degrees, with Tony and Donald making it a requirement while Steve, Bruce, and Natasha used it as an optional part of the class.

Theme 6: Future ALEKS Use

All teachers stated they would continue to use ALEKS and that they would use it in a similar capacity to the way that they have used it during the year of the study. Many of the teachers mentioned ways they would add or change their use of the tool. Steve and Tony mentioned wanting to make better use of ALEKS for entrance and exit slips. Many teachers wanted to use the My Path portion of ALEKS more often and more effectively.

Specifically referencing using the individualized pathway more, Natasha said in the third interview: "I really want to give those students opportunities to just be able to do a little bit more working and practice on their own." A few teachers brought up doing more differentiation using ALEKS and explaining the underlying purpose of using tools to help students use it more effectively. Donald and Bruce hoped to have students collaborate and communicate more about their mathematical understanding. For example, in the third interview, Bruce commented on his desire to have students work together: "Get kids working on ALEKS, working together in the classroom, and see kids sitting at a round table." Overall, the teachers in the study had a desire to continue to use ALEKS and to improve the way they use it. When asked about the potential for students to be back in the classroom and how that might impact their use of ALEKS, classroom teachers hoped to have the students interact more with each other, to use the program more for entrance and exit slips, and to give more in-person feedback.

Research Question 1 Summary

The interviews revealed several themes that addressed the research question of what strategies were used by teachers with the ALEKS program: (1) Assessment, (2) Data Analysis, (3) Practice of Learning Objectives, (4) Individual Pathways, and (5) Future ALEKS Use. All of the teachers used ALEKS to provide assessments for students with some teachers supplementing their use with student explanations. These assessments were analyzed by teachers using the data analysis tools in ALEKS. All of the teachers utilized the built-in feedback in ALEKS and took advantage of the data-analysis tools to provide feedback to students. Natasha and Steve specifically mentioned using the data-analysis tools to find classwide struggles to address. Donald, Tony, and

Bruce used the data-analysis tools to give individualized feedback to students. Teachers used ALEKS as a means of providing practice for students in two ways: (1) by creating assignments that connect to the content they are teaching in class and (2) through an individualized pathway for students to practice mathematics and advance through topics at their own pace, making use of the algorithms and tools built into ALEKS. The teachers in this study varied in how they provided practice to students. Tony and Donald mostly used the individual tools, Natasha and Steve used the assignments in ALEKS to practice topics taught in class, and Bruce used both of the tools. All of the teachers in the study stated that they intended to use ALEKS in the future and intended to use it in a way that is similar to how they have used it in the past.

Research Question 2

Research Question 2: How do high school mathematics teachers perceive the ease of use of the adaptive learning tool ALEKS in their classrooms/classes?

Data from the interviews underwent multiple rounds of coding and was then organized into a table that compares how teachers perceived ALEKS's ease of use. This table is displayed in Appendix E. The two themes that came out of the data analysis were Easy to Use and Minor Struggles/Limitations. In this section these two themes are discussed in terms of how they contribute to answering this research question. These themes are based on the codings presented previously in Table 4.3

Theme 1: Easy to Use

The overall opinion of the participants in the study was that they found ALEKS to be easy to use and navigate. Steve described his experience with ALEKS: "I thought it would be user-friendly and after using it I found it to be even better than I expected."

During his first interview Tony stated, “I find it easy to use, easy to navigate, and a lot easier than last year.” More specifically, since teachers often used ALEKS for creating assignments and assessments, several of the participants discussed how easy it was to find objectives and questions. Natasha brought this up in the second round of interviews, saying, “Their objectives are very little and are detailed, so every problem that I want to assign has a description which is long enough to know what is in the problem.”

Theme 2: Minor Struggles/Limitations

Although the sentiment of the teachers was that ALEKS was easy to use, they did bring up some struggles that took them some time to figure out. Steve brought up in the second interview that the “only thing that's difficult sometimes is in finding where stuff is. Like, I mean topic organization; it is just sometimes tedious. It isn't difficult, it just takes some time to sort through.” Most teachers acknowledged that it took some time to figure out ALEKS at first, but that it wasn’t difficult. Bruce was one of the only teachers that voiced some of the struggles he had, stating in interview three that “it wasn't as easy as like, turn it on and kids learn math, you're done, have a great day.” He also brought up that it was a little overwhelming because of all that ALEKS offers.

The data analysis generally revealed that teachers were satisfied with how easy ALEKS was to use. However, they did bring up some limitations that hindered their perceptions of how easy the tools were to use. Steve wanted to be able to write his own questions. Donald and Tony brought up wanting to have more control over the assignments that students could have access to in their individualized pathway. Bruce noted the limitations of the technology with ALEKS. The iPad would sometimes freeze or crash, and there was some frustration with ALEKS marking questions wrong because students did not write them in the correct form.

Research Question 2 Summary

In summary, the findings connected to answering the question of what the teachers' perceptions were related to the ease of use of ALEKS revealed that teachers in the study found the tool to be easy to use. They did need time to become familiar with the program, however, and there were some challenges or aspects associated with the use of the tool that they would have liked to be different. All of the teachers commented throughout each interview that ALEKS was easy to use. Some of the teachers articulated specific aspects related to assignment creation that they found particularly easy to use. Many of the teachers brought up that they just needed some time using the tool. Some teachers had some struggles with topic organization, technical difficulties, limitations with not being able to write their own questions, and a need for more control over assignments.

Research Question 3

Research Question 3: What are high school mathematics teachers' perceptions of the usefulness of the adaptive learning tool, ALEKS in high school mathematics classes?

To answer this question, the data from the interviews underwent multiple rounds of coding and was then organized into a table describing the usefulness of ALEKS across participants. This table is displayed in Appendix F. Several themes came out of the data analysis: (1) Instructional Tools, (2) Assessment Tools, (3) Personalization, (4) Negative Perceptions, and (5) Remote Learning Usefulness. These themes were based on the codings from Table 4.4. They contribute to answering this research question and are discussed in detail in this section.

Theme 1: Instructional Tools in ALEKS

Teachers provided a variety of explanations about the usefulness of the ALEKS tools. Most of the teachers described the explanations and tutorials as being useful. For example, in the second interview, Donald brought up the usefulness of the accessibility of explanations in ALEKS:

> They have a button they can just push that takes them right to an explanation of the problem they're working on right then. That's accessible. So we can make that learning accessible to the students. I think that's very powerful, very useful for teaching.

Steve specifically cited the quality of questions asked in the ALEKS system as useful in his teaching, stating in the second interview that ALEKS "does give you some of that reasoning and conceptual understanding." Feedback was commonly cited as a useful instructional tool within ALEKS. The ability of the program to provide immediate feedback to the students outside of class time was cited especially. Natasha mentioned how useful the feedback had been in the second interview:

> Immediate response, immediate feedback on how they're doing with the objectives outside of class. When we are remote we don't have that much time together. Twice a week, it's not a lot so they can practice. They are expected to practice on their own and ALEKS is great for providing feedback to the students.

Several teachers brought up the ability of ALEKS to help with efficiency, with planning, and with providing practice for students. Steve, in the second interview, referring to how helpful ALEKS is for providing extra practice stated that "in one respect it allows me to minimize time on remediation and maximize time on new instruction."

Theme 2: Assessment Tools in ALEKS

Several teachers cited the ability to give secure assessments, the ability to generate custom assessments from learning objectives, and the ability to manipulate the time constraints as useful aspects of the ALEKS program. Specifically, Steve, Bruce, Donald, and Natasha pointed out the usefulness of the tools ALEKS provides for assessments. For example, Natasha, in her interviews, discussed that ALEKS allowed her to change both the time limits and the availability to access "helps", and allowed for students to be able to be retested on specific questions. Donald, in the first interview, also stated that he believes copying and cheating was minimized during assessment because it "is really helpful that students can all have different questions. I feel that that minimizes copying and minimizes cheating and really gets what they seem to know."

Theme 3: Personalization & Differentiation

Teachers brought up, on several occasions, that they found many of the features offered in ALEKS for personalized learning and differentiation to be useful. They also felt that the tools in ALEKS helped them to provide more opportunities for differentiation. Steve mentioned in more than one of his interviews that he "really liked, from the homework perspective, the built-in differentiation." Natasha, Tony, and Donald all mentioned that ALEKS was useful because it could provide for individual gaps that students had in their learning. In particular, Donald found the program to be useful in his class because it met students where they were. In the third interview, he referenced his students having to explain topics in ALEKS:

> If they have 70 topics at the beginning, their questions might be a little harder, but they should be ready to do that, and so I feel like that helps to build confidence. I don't care how easy or hard the topic is, you should be able to explain wherever you are. I feel like that's been helpful because it's not just a one-size-fits-all class.

Not all teachers mentioned the importance of question generation, but several teachers discussed how useful it was for students to receive multiple attempts on questions and assessments. Steve, in the second interview, stated that having an unlimited amount of problems for students was helpful "because of the way it generates multiple problems, examples, and allows for students to kind of fail into success in a more streamlined manner compared to me creating multiple worksheets."

Theme 4: Negative Perceptions

Although the overall perception from the group of teacher participants was positive, many of the teachers had some negative perceptions as well. Negative perceptions varied across teachers, but some discussed not getting enough feedback about the specifics of what the students might be struggling with. Steve in particular brought up in the second and third interviews that he felt the feedback he received in ALEKS wasn't specific enough:

> ALEKS from a teacher's standpoint lacks a little bit because I can't see those things. It's not specific enough that I can go and diagnose the specific issue.

> I need to see really just visually not that they were just right or wrong, but I need to be able to see where the mistakes are.

Other issues came in the form of how the feedback is delivered from ALEKS to students when they get a problem wrong. Bruce and Donald mentioned that they felt the written explanations were challenging for some students to understand. Bruce mentioned that the explanations in ALEKS were "math for math teachers and not math learners." This sentiment was shared by Donald when asked about the usefulness of ALEKS in the third interview: "I had to do a lot of explanations and instructions. ALEKS doesn't embed that. They've got their explanations, but they kind of are assuming that you're already getting it." Some other negative perceptions expressed by the participants in terms of the usefulness of ALEKS addressed minor challenges and limitations. Tony, in the third interview, expressed that using ALEKS for personalized learning made it challenging to plan a lesson because students were all working on different learning objectives based on their ALEKS My Path. Bruce expressed that sometimes ALEKS would not accept different forms of a response and would mark it wrong for students. Donald explained that even though ALEKS was a useful tool, teachers "can't just say work on your learning path. That's not going to lead to tremendous growth."

Theme 5: Remote Learning Usefulness

All of the teachers found ALEKS to be especially useful in a remote learning environment for various reasons: (1) ability to access data on student task completion, (2) secure and customizable assessments, (3) the instructional tools, and (4) feedback. Due to the limited amount of time that teachers had with students during the course of this study (because of the effects of COVID-19), they felt ALEKS provided them with several resources and the ability to help students to learn at any time. For instance, in the second interview, Steve mentioned that the data provided by ALEKS helped him to see that students were independently practicing the course content, stating that it "makes it so much easier because now it is not a mystery what happened at home." The ability of the program to provide secure assessments and the instruction provided by the tool are the main reasons Natasha found ALEKS to be useful. Describing the assessment features in the third interview, she stated:

> Because of remote learning, it's a good tool for formative learning because it gives students feedback right away. Since they do not have a teacher necessarily with them, it allows them to practice anytime. It's especially useful in the setting we are in. When students can test anytime it's a great opportunity for students to test on their own time so we don't have to use our already short days that we have together.

Research Question 3 Summary

During the course of three interviews, the teachers in this study provided several pieces of evidence suggesting that they perceived ALEKS to be a useful tool in their teaching. Although their perceptions on what was specifically useful to them varied from teacher to teacher, several themes emerged. To determine a possible answer to this research question, several themes were drawn and discussed: (1) Instructional Tools, (2) Assessment Tools, (3) Personalization, (4) Negative Perceptions, and (5) Remote Learning Usefulness. Teachers in this study found the instructional tools in ALEKS to be helpful to them because ALEKS provided students with immediate feedback, accessible instruction in the form of explanations, and improved the efficiency of providing practice for students. However, some teachers did express some negative perceptions regarding how useful the explanations were in ALEKS because of the difficulty students had with understanding them. Teachers also found the assessment tools to be useful in helping to identify gaps in student learning at the class level and at the individual level. This was helpful for teachers when planning lessons, personalizing learning, and differentiating instruction. The assessment tools were found to be especially useful in a remote learning environment since the students could access them whenever they wanted, and the teacher could analyze the classroom data in terms of engagement and level of understanding. Although some negative perceptions of ALEKS were discussed by teachers, the overall conclusion was that teachers generally perceived ALEKS to be useful for their teaching.

Chapter 4 Summary

The purpose of this study was to understand what teaching strategies high school mathematics teachers used with the ALEKS system and to examine their perceptions of its ease of use and usefulness. This study utilized a basic qualitative design to collect data from the first hand experience of high school mathematics teachers who used ALEKS in their classrooms. Five high school math teachers with between 12-35 years of experience in teaching and at least two years of experience using ALEKS were invited to be a part of the study. Five teachers were selected using purposeful sampling, and each one participated in three interviews with the researcher throughout an academic school year (2020-2021). The data was analyzed using multiple coding procedures, data organization methods, and visualization techniques in between each interview and upon the conclusion of the study. This process helped the researcher to develop themes, to add and alter interview questions, and to determine possible answers to the research questions.

The results of the analysis reveal several themes in the ways ALEKS was used by teachers in this study. All of the teachers used ALEKS to assign mathematical tasks for students to complete in the form of practice problems and assessments. Some of the teachers utilized an individual pathway for students to follow where they could work at their own pace. All of the teachers set goals and expectations for students in terms of what they should complete in ALEKS and made use of the data-analysis reports in class to monitor student progress and achievement on assigned tasks. Some teachers relied on the tools in ALEKS to provide feedback to students, but most utilized class time to provide students with feedback on mathematical topics by providing explanations and reflection activities. All of the teachers stated that they would use ALEKS in the future if given the opportunity and that they would use it in a way similar to the way they have used it in the past. Many of the teachers would use ALEKS more for entrance and exit slips and would like to use it in class more often in a way that allowed for the students to interact with each other.

In terms of the perceptions of teachers, the data analysis suggests that teachers in this study generally felt that ALEKS was easy for them to use. Several of the teachers stated that they felt that ALEKS was easy to navigate and, specifically, made it easy for them to find questions they wanted to use for assessments and practice for students. Most of the teachers mentioned that, although ALEKS was not difficult for them to use, they did reference the fact they just needed some time and experience using it. Some of the teachers mentioned the challenges of using ALEKS: the vast number of tools, a lack of control over certain aspects of the program, and the inability to do certain tasks like write their own questions. All of the teachers felt comfortable enough with ALEKS that they planned to continue its use into future school years.

Based on the three interviews, teachers found ALEKS to be useful in their classes in several ways. Teachers found that the explanations and feedback given in ALEKS were helpful to students because the feedback was instant and accessible at all times. They found these aspects to be especially useful given that all of the teachers were teaching in a remote setting where they had less access to the students compared to prior years. Teachers found ALEKS to be useful for giving assessments and for using the data to make decisions about their teaching. This was especially true when it came to personalized learning and differentiation opportunities since students could utilize the question generation aspect of the tool and the ALEKS My Path to work at their own pace. Although the teachers were able to point out several aspects of ALEKS that were useful in their teaching, there were also some negatives that they pointed out. These negative perceptions were technological challenges, the inability to see student work in the program, and that the explanations given in ALEKS could sometimes be confusing for students to read. Findings from the data analysis does show strong support for ALEKS being a useful tool for teachers while recognizing some areas that could be improved.

CHAPTER 5: DISCUSSION

Introduction

The purpose of this study was to understand what teaching strategies high school mathematics teachers used with the ALEKS system and to examine their perceptions of its ease of use and usefulness. This study followed a basic qualitative design in which five high school mathematics teachers were interviewed three times throughout an academic school year. Their responses were collected, organized, and analyzed. In this chapter, the results of this study are described in greater detail by connecting them to the existing literature related to teaching strategies, TAM, adaptive learning tools, and the use of technology in mathematics classrooms. This chapter also provides the implications of this study, recommendations for future research, and conclusions from the study.

Discussion of Findings

In this section, the findings of the study are discussed and connected to the existing literature. This is done by breaking down each question into the themes that were generated through the data analysis process. Connecting the findings of this study to the current research related to teaching mathematics, to adaptive learning tools, and to ALEKS helps to determine answers to the research questions.

Research Question 1

Research Question 1: What teaching strategies are high school mathematics teachers implementing while using the adaptive learning tool, ALEKS?

Theme 1: Assessment

One of the most common strategies in which the teachers in this study used ALEKS was assessing student learning of course objectives and measuring their progress in the ALEKS My Path. Teachers used the ALEKS quizzes and tests as both formative and summative assessments throughout the school year. Using various classroom assessments is supported in the literature as one of the most important aspects of teaching because it has a strong influence on learning when followed with feedback (Havnes et al., 2012). Formative assessments are especially helpful for student learning because they allow teachers to make adjustments based on students' needs (Anthony & Walshaw, 2009; Arends et al., 2017; NCTM, 2020b). Teachers described using the assessments as a means of collecting data about student progress in order to identify student understanding, provide feedback, and determine future classroom decisions.

The data analysis also revealed that many of the teachers in this study supplemented their assessments by having students submit the work and notes they used to solve problems on their assessments. These teachers said they wanted to see work from the students so that they could see their mathematical processes and reasoning. Asking students to share their reasoning and process is supported in the literature on effective teaching practices (Arends et al., 2017; NCTM, 2020c). The NCTM (2020a) lists several research-based standards for effective mathematics instruction that they recommend for teachers. One standard is that teachers implement tasks that promote reasoning and problem solving and elicit and use evidence of student thinking. One of the teachers in this study asked students to provide video evidence from students in which they described a topic that they learned in ALEKS. This strategy was supported by the research on providing opportunities for students to engage in mathematical reasoning (Caro et al., 2016; NCTM, 2020c).

Theme 2: Data Analysis

Along with using ALEKS for assessment of student progress, all of the teachers in this study used the data analysis features in ALEKS. These tools included the ALEKS pie chart showing the percentage of the learning objectives a student had completed, the data displaying the amount of time students spent engaged with the program, and the detailed breakdown showing which questions students answered correctly/incorrectly on an assignment. Teachers used this data for several teaching strategies. They used the pie chart and details of student engagement to have conversations with students about their progress and goal setting. This strategy of a teacher using adaptive learning tools to take on the role of facilitator by tracking progress of learning mastery is consistent with recommendations from literature on teaching mathematics with technology (Bray & Tangney, 2017; Kynigos, 2019; Smith, 2018). No relevant research was found specifically related to the role of a teacher as facilitator using adaptive learning tools outside of publications from ALEKS. Teachers also used the detailed question breakdowns on assignments and tests to make plans for future lessons and provide individual feedback for students or groups of students. The ability of teachers to collect data and provide feedback are examples of how adaptive learning tools can enhance student learning (Smith, 2018).

Theme 3: Feedback

ALEKS gives immediate response feedback to students through hints and written explanations (ALEKS, 2021b). Teachers in this study stated that they relied on this computer-based feedback when the students were completing assignments or working on the ALEKS My Path. The research related to computer-based feedback is favourable to using it to enhance student learning (Hattie, 1999; Roschelle et al., 2010). The feedback given in ALEKS has been supported by research as being especially useful because it is immediate and specific (Corbett & Anderson, 2001; Marzano et al., 2001; Schute, 2008). Teachers also gave feedback, via the data analysis features of ALEKS, to students during class based on what they saw students struggling with on their assignments. Teachers gave feedback to the whole class or to individuals depending on the results of an assignment. As a teaching strategy, quality feedback is considered to be one of the most effective for enhancing student understanding (Barry, 2008; Hattie, 1999; Havnes et al., 2012). No relevant research was found regarding the use of feedback with ALEKS. The teachers in this study stated several times, throughout the interviews, that they used ALEKS as an avenue to provide feedback to students.

Theme 4: Practice of In-Class Objectives

Teachers in this study created ALEKS assignments for students to practice learning objectives. All of the teachers set an expectation for the amount of practice a student should complete during each week in terms of either the number of assignments they should complete or the amount of time they should spend engaged with the program. Research related to effective teaching practices has supported communicating with students about their progress and goal-setting (Bartell et al., 2017). Teachers made sure that students kept up with the assigned practice by checking for mastery of assignments or on the amount of time spent working.

Since ALEKS has the ability to regenerate multiple questions for students, teachers were able to provide students with a considerable amount of practice. Research has shown that this strategy of providing repetitive exercises is commonly used by high school mathematics teachers and has shown evidence of being effective (Cardino & Cruz, 2020). However, practice problems in ALEKS where questions are regenerated may be considered to be a drill and practice type activity. Research has shown that using technology for drill and practice activities has not had much of an impact on student achievement (McCulloch et al., 2018).

Teachers used ALEKS for direct instruction or would allow students time to complete ALEKS assignments during class. They stated that they would bring up ALEKS problems on their screens (when teaching remotely or in person) to go over concepts or common errors with students. Teacher-directed lessons are another teaching strategy that has shown some evidence of being effective (Cardino & Cruz, 2020). In these lessons, teachers would model mathematical processes and would correct misconceptions (Anthony & Walshaw, 2009; Shute, 2008). Three of the five teachers in this study allowed students to work on ALEKS while giving feedback and instruction to students or groups of students. Allowing students to practice ALEKS problems in class provided teachers with opportunities to give explanations and immediate feedback which Marzano et al. (2001) believe to be important for student achievement.

Theme 5: Individualized Pathway

All of the teachers in this study used the initial assessment in ALEKS to gain an understanding of the mathematical knowledge of their students. Teachers used this information in various ways. Four of the teachers used the initial assessment to determine a starting point for their students on the ALEKS My Path. Giving an initial assessment is supported by Bartell et al. (2017) in their research on equitable practice, stressing the importance of recognizing where a student is at and then building on their current understanding. Shute and Zapata-Rivera (2012) have supported having ALEKS present adaptable content because students often come into classes with differences in knowledge, abilities/disabilities, and demographic/socioeconomic differences. Teachers in this study noted that the initial assessment helped them to collect information on student understanding so they could make classroom decisions. There has been some precedent in the research related to using the ALEKS initial assessment as a placement test. Woods (2017) cites several studies in which ALEKS has been used as a placement test for college-level classes. Although teachers did not use the initial assessment to place students into a specific class, all of the teachers in this study used the initial assessment to start the students in ALEKS My Path. This aligns with the NCTM (2020c) suggestion to use previous evidence of student learning when adjusting instruction and aligning learning goals.

The four teachers in this study who used the ALEKS My Path allowed students to use the tools in ALEKS to learn a progression of mathematical topics based on the results of the initial assessment. These teachers often communicated with students about their progress and acted more as facilitators of learning. This teaching strategy of acting as a facilitator is supported in the literature because it takes a non-traditional approach. This helps teachers to realize the benefits of the technology and to use a student-centered approach (Bray & Tangney, 2017; Levin & Wadmany, 2006; Monaghan, 2004). ALEKS (2020c) has suggested in their teaching guide that teachers act more as facilitators by providing structure, support, and reinforcement. Teachers provided this support by monitoring progress, providing individualized feedback, and generating custom assignments when needed.

Theme 6: Future ALEKS Use

Teachers in this study were asked to discuss how they planned to use ALEKS in the future. They stated that they would use it in a similar fashion, with some teachers commenting on enhancements or changes that they would make. Some of the teachers indicated that they would make more and better use of entrance/exit slips so that they could see more student work and give more in-person feedback. This desire to have students use ALEKS in class in order to see student work is supported by the NCTM (2020a) which cites research-based strategies of having students display evidence of student thinking. Using ALEKS more often in class to provide immediate feedback to students matches previous research supporting providing specific feedback (Barry, 2008; Hattie, 1999; Havnes et al., 2012). Teachers were also asked how they would use the tool if they were to have students in-person more often. Some of the teachers stated that they would have the students engage in more collaborative work where they could communicate about ALEKS problems. Communication is a valuable teaching strategy for both students and teachers to engage in, especially via class discussion of mathematical procedures, solutions, and ideas (Arends et al., 2017; NCTM, 2020a).

Research Question 1 Summary

This research question attempted to understand the teaching strategies used by teachers with the ALEKS system. The findings of this study indicate that teachers used several teaching strategies related to assessment, data analysis, feedback, and instruction techniques. They used ALEKS to provide assessments for students, the results of which they then used to analyze student understanding. They were then able to provide feedback to students on their misunderstandings at both an individual and class level. Feedback to students is considered to be one of the most effective strategies for student learning (Barry, 2008; Hattie, 1999; Havnes et al., 2012; Marzano et al., 2001; Schute, 2008). Research on effective mathematics teaching strategies has also suggested focusing on reasoning skills (Arends et al., 2017; Caro et al., 2016; NCTM, 2020c).

Several teachers indicated having students supplement their work in ALEKS with written or recorded explanations so they could assess their mathematical reasoning. Teachers used ALEKS to provide practice for students where they could rely on the immediate feedback given through the program. Computer-based feedback has shown evidence of being effective for student learning (Hattie, 1999; Roschelle et al., 2010). Many teachers made use of the ALEKS My Path to allow students to work at their own pace. In this scenario teachers acted as facilitators who could provide for individual needs, communicate with students about their progress, set goals, and give feedback. All of which have been supported by the research related to effective teaching strategies (Arends et al., 2017; Bartell et al., 2017; Marzano et al., 2001).

Research Question 2

Research Question 2: How do high school mathematics teachers perceive the ease of use of the adaptive learning tool ALEKS in their classrooms/classes?

Theme 1: Easy to Use

Teachers had prior experience with using ALEKS and various types of training before this study was conducted. Some received training from colleagues and from faculty at a local community college. Some of the teachers were self-taught using the ALEKS resources or learned by spending time interacting with the program. No matter their training or experience level, all of the teachers stated that ALEKS was easy for them to use and navigate. TAM has suggested that one of the most influential factors in a person's acceptance and use of a technology tool is its perceived ease of use (Davis, 1989). The beliefs and attitudes of teachers towards technology have an influence on their perceptions of using technology tools (Ertmer et al., 2012; Karatas et al., 2017; Kopcha, 2012; Pierce & Ball, 2009; Wachira & Keengwe, 2011). These beliefs and attitudes can be influenced by the level of support teachers receive in terms of training (Goos & Bennison, 2008; Wachira & Keengwe, 2011). Also, participants cited multiple ways in which the design features of ALEKS made it easy to use. In TAM, external variables such as the design features of a tool can influence a teacher's perceptions of ease of use (Davis, 1989; Mugo et al., 2017; Venkatesh & Davis, 1996).

Theme 2: Minor Struggles / Limitations

Although teachers indicated that they found ALEKS easy to use, many of them acknowledged that they needed to spend some time learning the tool and figuring out how to find specific questions or objectives that they wanted to use for an assignment. The need for time to learn how to use technology is supported in the literature because studies have shown that teachers are unlikely to use a technology tool if they are not given time to learn how to use it (Wachira & Keengwe, 2011; Kopcha, 2012; Rogers, 2000). The findings of this study show that teachers were given and spent time learning how to use ALEKS and therefore used the tool throughout the course of this study.

Two of the teachers also noted some limitations of or technical difficulties with ALEKS. One teacher indicated that he wished ALEKS was able to provide more feedback for him other than whether students were getting problems right or wrong. Another teacher mentioned technical issues with ALEKS related to using it on an iPad and some answer-entry issues. If teachers experience difficulty using a technology, it can have a negative impact on whether they use it or not (Kopcha, 2012). However, the limitations and difficulties faced by these teachers did not inhibit their desire to use ALEKS, nor did they change the teachers' view that ALEKS was easy for them to use.

Research Question 2 Summary

TAM has suggested that the ease of use of a technology tool has an impact on its acceptance and on whether that tool will be adopted by a user or not (Davis, 1989). Several factors can influence an individual's perception of ease of use when it comes to technology, specifically the design features of the tool and the level of support one needs to use it (Davis, 1989; Mugo et al., 2017; Venkatesh & Davis, 1996). The teachers interviewed in this study consistently stated that they felt ALEKS was easy to use and supported this perception by providing examples of design features in the program and sharing their experience/training with the tool. Difficulty using a technology tool can have a negative impact on adoption by a user (Kopcha, 2012). Some teachers expressed that they needed time to learn the tool and that they had some minor challenges. Even with those challenges, however, teachers did have an overall perception that ALEKS was easy to use. The findings of this study were consistent with prior research related to TAM in which teachers found ALEKS to be easy to use and planned on using the tool in the future (Sauro, 2019; Yousafzai et al., 2007).

Research Question 3

Research Question 3: What are high school mathematics teachers' perceptions of the usefulness of the adaptive learning tool, ALEKS in high school mathematics classes?

Theme 1: Instructional Tools

ALEKS has numerous tools built into its program that were considered useful for teachers. The findings of this study indicate that teachers perceived the resources and explanations in ALEKS to be helpful for students because they made learning accessible for the students whenever they needed it. Research has suggested that, for teachers to fully realize the benefits of technology, they need to be facilitators of learning (Bray & Tangney, 2017; Kynigos, 2019). Teachers in this study found ALEKS to be useful because it made practice problems, explanations, and feedback available to students at all times. Along with accessibility, teachers found the feedback given to students to be useful as well because of how immediate and specific it was. Computer-based feedback, when delivered immediately with error correction, has shown evidence of being effective (Corbett & Anderson, 2001; Marzano et al., 2001; Schute, 2008). One teacher noted both the quality of the questions asked in ALEKS and how it provided evidence of students' conceptual understanding, a quality supported by the NCTM (2020a) as helpful in building procedural fluency.

Theme 2: Assessment Tools

When discussing what made ALEKS useful, teachers brought up the ability to provide secure and customized assessments. This was especially important in the year of this study because of the need to engage students in remote learning. Teachers also cited that they found the ability of ALEKS to generate different questions for each student helpful in order to minimize cheating and provide students with multiple opportunities to re-test. Customizable assessments allowed teachers to adjust times, questions, and access to help in order to differentiate for students. These adjustments to assessments have been supported by Tomlinson, Moon, & Imbeau, (2013) in their suggestions for differentiating student assessments.

Theme 3: Personalization

Although the teachers in the study used the ALEKS My Path to varying degrees, they acknowledged the usefulness of ALEKS from a personalization standpoint. Personalized learning in this study matches the definition provided by Johnson et al. (2016) which characterises it as students being allowed to proceed at their own pace with learning goals that are based on mastery of achieving them. Participants in this study indicated that two of the benefits of ALEKS were that it allowed them to address individual gaps in student understanding and that the question generation allowed students to practice as much or as little as needed. The use of computer systems to help teachers with decision making is supported in the literature because evidence has shown that teachers can use them to help meet student needs and improve student learning (Peshek, 2012; Ysseldyke & Tardrew, 2007). The adaptability of the ALEKS program was useful for teachers and supports what the research has shown about what is beneficial about the capabilities of adaptive learning tools (Bulger, 2016; Hsieh et al., 2013; Murray & Pérez, 2015).

Theme 4: Negative Perceptions

Although teachers stated many ways that ALEKS was considered to be useful, in some ways they did not find ALEKS to be effective for their teaching. One of these criticisms was about the quality of feedback and data it provides for teachers. Although ALEKS provides data on a student's success level on assignments, it is mostly limited to whether they completed the problem correctly or not. Research has suggested that effective mathematical teaching involves tasks that promote reasoning and problem solving (Anthony & Walshaw, 2009; Caro et al., 2016; NCTM, 2020a). Some of the teachers felt that they needed to see student work in order to understand their mathematical reasoning and processes and that they had to find ways to evaluate student work outside of ALEKS.

Although teachers found the explanations in ALEKS to be useful, some found that they were sometimes difficult for students to comprehend due to the use of mathematical terms and reading level required. Azevedo et al. (2005) suggested that without scaffolding, learning complex topics with adaptive learning tools can be challenging. Participants in this study also felt that the way answers were accepted by the computer was not useful because it would not accept certain forms or would mark a question wrong even though it was only a minor error. The teachers in this study acknowledged that ALEKS was not able to provide everything that they needed. This is consistent with prior research on the limitations of adaptive learning tools. This research recognizes that teachers need to plan how they will use the tools in order to use them effectively (Baker, 2010; Liu, 2017; Longnecker, 2013).

Theme 5: Remote Learning Usefulness

Due to COVID-19, all of the teachers in this study were required to teach in a remote learning environment for all or part of their class time during the year this study was conducted. Under these circumstances, teachers found ALEKS to be especially helpful because of the limited amount of time that they were able to be with students. All of the teachers stated that they had less class time with students compared to prior years and had significantly less time with them in person. They stated that ALEKS was useful because it allowed the students to access resources whenever they needed them. Since students had limited access to their teacher, teachers felt that ALEKS could still provide students with practice, feedback, and assessments which are examples of researched-based rationale for using adaptive learning tools (Bulger, 2016; Hsieh et al., 2013; Murray & Pérez, 2015). They also cited the ability to access the data on what students were doing outside of class as helpful to facilitating learning. Given that teachers were not working with students every day, they needed to transform their role more into that of a facilitator, a move supported by what research has suggested about utilizing technology in teaching mathematics (Bray & Tangney, 2017; Levin & Wadmany, 2006; Monaghan, 2004).

Research Question 3 Summary

According to TAM, the usefulness of a technology tool has an impact on its acceptance and on whether that tool will be adopted by a user or not (Davis, 1989). One of the factors that can influence an individual's perception of usefulness when it comes to technology is its design features (Davis, 1989; Mugo et al., 2017; Venkatesh & Davis, 1996). Teachers in this study perceived that the tools in ALEKS were useful to them in many ways. They were able to share details about how ALEKS was useful to them. They mentioned its ability to provide instructional tools, its ability to provide reliable and customizable assessments, and its ability to allow for personalization for students. These examples of usefulness were also supported by the research related to technology use in mathematics classrooms, differentiation, and the capabilities of adaptive learning tools (Bray & Tangney, 2017; Bulger, 2016; Hsieh et al., 2013; Kynigos, 2019; Murray & Pérez, 2015; Peshek, 2012; Tomlinson et al., 2013; Ysseldyke & Tardrew, 2007). Although some teachers shared some negative perceptions about the usefulness of ALEKS, all of the teachers in this study stated their intention to use ALEKS in the future. This seems to reflect that the positive perceptions outweighed the negative ones. This is consistent with prior studies related to TAM that have suggested that positive perceptions of the usefulness of a technology tool influence the behavioral intention of a person to use the tool in the future (Sauro, 2019; Yousafzai et al., 2007).

Discussion of Findings Summary

In this section the findings of the study were discussed as they connect to the teaching strategies used by teachers with ALEKS and their perceptions of its ease of use and usefulness. Findings of each research question were discussed in terms of the major themes found when analyzing the data from teachers' interviews, and then these findings were connected to the current literature. In regard to the teaching strategies used, several connections were able to be made between how teachers used ALEKS and effective teaching strategies in mathematics classrooms. Teachers in this study made use of assessment and data analysis tools in ALEKS to analyze student understanding, provide feedback, and make adjustments to their teaching. They also made use of feedback techniques, using the computer generated feedback in ALEKS to provide students with immediate feedback. Teachers provided feedback to students related to their misconceptions and progress toward learning the assigned objectives. They made use of ALEKS practice problems to provide explanations and also provided opportunities for students to practice their fluency with mathematical topics. All teachers stated that they plan to use ALEKS in the future and would use the tool for students to collaborate and communicate with each other. Many of the teaching strategies used by teachers in the study have been supported by the research related to effective teaching practices for mathematics. Specifically, the teachers' use of feedback (Corbett & Anderson, 2001; Marzano et al., 2001; Schute, 2008), the teachers providing opportunities for students to reason mathematically (Caro et al., 2016; NCTM, 2020c), and the teachers acting as facilitators for student learning (Bray & Tangney, 2017; Levin & Wadmany, 2006; Monaghan, 2004) have shown evidence of being effective strategies.

Participants in this study indicated that they felt ALEKS was easy to use and useful. They also stated that they would continue to use the tool in the future. This was consistent with previous research related to TAM, which served as the theoretical framework of this study. The model suggests that if an individual finds a tool to be easy to use and useful then it has a positive effect on the behavioral intention to use (Davis, 1989). TAM also states that the design features of a technology tool can influence its ease of use and usefulness (Davis, 1989; Mugo et al., 2017; Venkatesh & Davis, 1996). The findings from the interviews indicate that teachers were able to cite several ways in which they found ALEKS to be easy-to-use and useful that are supported by research related to adaptive learning tools, technology use, and effective teaching strategies. Some research-supported ways that teachers found ALEKS to be useful were its ability provide question generation to build procedural fluency (NCTM, 2020a), customizable assessments to provide differentiation (Tomlinson et al., 2013), immediate feedback (Corbett & Anderson, 2001; Marzano et al., 2001; Schute, 2008), and learning opportunities for students (Bray & Tangney, 2017; Levin & Wadmany, 2006; Monaghan, 2004).

Implications

The findings of this study could have several implications for technology use in high school mathematics classrooms. Teachers and school districts could benefit from the findings of this study when deciding on whether or not to use adaptive learning tools, or, if they are planning to use them, on how the technology could be implemented. The findings of this study could even provide beneficial information to ALEKS or other technology companies specializing in adaptive learning tools. This section will describe the implications of the findings of this study.

There has been an abundance of research related to the adaptive learning tool ALEKS that has attempted to measure the effectiveness of the tools on academic performance as measured through test scores (Fang et al., 2019; Goodwin, 2017; Karner, 2016; Mills, 2018; Nwaogu, 2012; Richard, 2019; Sabo et al., 2013; Yilmaz, 2017). However, there have been a limited number of research studies that have explored teaching strategies using ALEKS (Benjamin, 2020; Padilla-Oviedo et al., 2016). Most of the information on how ALEKS is used by teachers has come from the actual company itself through their own publications (2020a; ALEKS, 2020c). This study adds to the body of research related to ALEKS and helps to fill gaps in the research by providing the voice of the teachers who are using the tool in their classrooms. This study provides accounts from actual teachers, using research independent of the company. This is significant because it not only fills gaps in the research related to ALEKS and adaptive learning tools, but it could also lead to more qualitative studies that attempt to explore how these tools are actually used by teachers.

This study provides accounts of high school mathematics teachers who used ALEKS in both a remote and in-person learning environment. The findings of this study could provide teachers with useful information on the ways in which they can incorporate teaching strategies with ALEKS. There are thousands of teachers who use ALEKS every year (ALEKS, 2020c), and this research could provide them with examples of what is useful about the tool and a rationale for how it could be easy to use for them. They could use the accounts of the teachers in this study to plan for their own use of ALEKS. This study could be especially helpful for teachers in a remote learning environment since all of the teachers in this study used ALEKS in such a manner during the course of this research. Teachers could use these accounts to determine whether the use of ALEKS aligns with their own pedagogy and if it could be useful in their own practice. The strategies discussed by the participants of this study could inform other teachers about how to implement ALEKS in their classrooms.

The findings of this study could be useful to school districts and school administrators as well. Since this study provides accounts of the teaching strategies used with ALEKS in high school mathematics classes, schools could determine whether use of the tool aligns with their schools' practices and policies. This research could also provide a rationale for schools deciding which technology products to purchase for their teachers, and for whether ALEKS aligns with their needs and budget. The teachers in this study shared several examples of the teaching strategies they used with ALEKS as well as the ways in which they found the tool to be useful and easy to use. Schools could use these examples to provide professional development on how to use ALEKS for those specific teaching strategies. Several teachers in this study indicated that they just needed some time exploring the tool and that they were able to be self-taught or that they learned through collaboration. Schools could benefit from this research by offering training that gives teachers time to explore ALEKS as well as time to work together on a plan to use the tool.

There has been limited independent research on the teaching strategies used by teachers with adaptive learning tools (Benjamin, 2020; Padilla-Oviedo et al., 2016; Wang et al., 2018). The ALEKS website has provided a publication on how teachers should use their tool (see ALEKS, 2020a) and another publication that shares accounts from teachers of how they used the tool and what they found useful about it (see ALEKS, 2020c). However, these suggestions and accounts come from ALEKS and not from an independent study. The findings of this study could provide ALEKS and other companies with similar tools the actual experiences of high school mathematics teachers. These experiences documented in this study share the teaching strategies that teachers used with ALEKS. Companies can use these accounts to enhance their products or to make changes to their tools in order to better meet the needs of teachers. For example, many of the teachers in this study shared some negative perceptions of ALEKS and some of the limitations of the product. ALEKS and other companies could use this information to make improvements to their tools based on the descriptions provided in this study. ALEKS could also use the feedback of the teachers in this study to help them provide training for teachers and schools.

This section described the implications of the findings from this study. This study adds to the research related to adaptive learning tools, and also helps to fill the gaps in the research by providing the voices of the teachers using ALEKS in their classrooms. Teachers could benefit from the findings of this study while deciding whether to use (or not use) ALEKS, when choosing the teaching strategies to implement with it, and when deciding how they can learn to use the tool. The findings of this research could also be used by schools who are interested in using ALEKS to determine whether or not to use the product, how the tool could be useful for their teachers, and how to provide professional development and training for teachers. Finally, ALEKS and similar technology companies could benefit from the findings of this study by using them to make improvements and changes to their product based on how teachers used the tool and what they found useful about it.

Limitations

This study adds to the research related to adaptive learning tools and also provides a source of information for schools and teachers. Although this study can contribute to the literature on adaptive learning and can provide examples of how ALEKS is used in high school mathematics classrooms, it has limitations and assumptions to be considered. This section describes these limitations and assumptions.

It is important to note that the size and scope of this study was relatively small and confined to the Chicagoland area. This study only focused on a small and diverse set of schools and teachers with no intention to be more generalized. This study also only explored the use of ALEKS over one school year that included the situations associated with the COVID-19 pandemic. Different contexts or longer use of the tool could lead to different experiences and perceptions of its ease of use and usefulness. Since ALEKS was the only adaptive learning tool that this study focused on, one cannot apply these generalizations to all adaptive learning tools as well. This was a study of one adaptive learning tool and its features, and its use may be different than others available to teachers.

There were also several additional situations in the study that may have had an influence on the teachers' experiences and perceptions. For instance, the five participating teachers had a variety of experiences using technology, with some teachers being more confident or supportive of technology integration in their classrooms than others. This study did not analyze the training or professional development that teachers received with ALEKS that could have had an impact on their experiences with the tool. There was neither any data collected nor any analysis of the level of support given to teachers from school administration on integrating technology or on using adaptive learning tools. Numerous studies have supported the idea that the teachers' confidence, training, and support from administration play a role in the level of technology implementation of a teacher (Goos & Bennison, 2008; Wachira & Keengwe, 2011).

This study also asked the teachers to give a first-hand account of their experiences and perceptions of using ALEKS in their classrooms. In this study, teachers' voices and opinions were important. However, this study assumed that these accounts were honest and that the experiences of the teachers were an accurate representation of what occurred in the classroom. Teachers were asked about their perceptions of the ease of use and usefulness of the ALEKS system in their classes. However, this study did not attempt to quantify ease of use or usefulness through an assessment of any sort. Rather, the goal of this study was to focus on how the teachers perceived the use of the tool.

Although the research design put measures in place to improve the trustworthiness of the data collected, the researcher conducted a significant portion of the codings and data analysis. The researcher's own bias may have had an influence on the codings or interpretation of teacher responses in the interviews. During the first round of coding, the researcher and his advisor independently coded the same interview document in order to discuss codings and future coding strategies. However, subsequent interviews were coded only by the researcher.

This study attempted to collect information from teachers regarding the teaching strategies they used with ALEKS and their perceptions of ease of use and usefulness of the tool. This study was limited to a small sample of teachers from a specific geographic area. Applying the findings of this study to a larger sample or another location could yield different results. This study did not attempt to analyze the level of training or confidence of teachers using ALEKS and how it might have impacted the ways they used the tool or their perceptions. This study also relied on teachers being honest about and forthcoming with their accounts of using ALEKS during the academic year in which this study was conducted.

Recommendations for Future Research

This section describes the recommendations for research that could expand on this study. The scope of this study was limited to a small group of teachers from the Chicagoland area and took place over just one academic school year. This study was also limited to five high school mathematics classes, and explored just one adaptive learning tool. Due to the impact of COVID-19, all of the teachers in this study taught the majority of their lessons in a remote teaching environment. This study followed a basic qualitative design where interviews with teachers were used as the primary source of data collection. This study attempted to understand the teaching strategies used by high school mathematics teachers and their perceptions of usefulness and ease of use, but did not include the voices of students or other stakeholders. Based on the scope of this study there are several avenues to expand upon the research conducted in this study.

This study took place in the Chicagoland area with five high school mathematics teachers using ALEKS over the period of one academic school year. Given that this study interviewed a limited number of participants, future researchers could attempt to duplicate this study with a larger or more diverse sample. By opening the study up to more teachers there could be a greater variety of classroom environments, backgrounds of teachers, and subjects taught with ALEKS. This study took place over just one academic school year. Future research could explore similar goals but over a longer period of time in order to determine whether their teaching strategies or their perceptions of its ease of use or usefulness change. This study also only explored the use of one adaptive learning tool, ALEKS. Future research could attempt to duplicate this study with other adaptive learning tools to compare strategies used and perceptions of usefulness amongst tools.

Although all of the teachers in the study taught a high school mathematics class over the course of this study, due to COVID-19, the learning environment for each varied between remote and in-person. Some of the teachers in this study were strictly remote, meaning that they had no in-person lessons or interactions with students. Some of the teachers taught remotely, but had time with students in-person each week. The amount of time spent remote versus spent in-person may have impacted the teaching strategies used or the perceptions of the teachers. Also, all of the schools in this study had 100% in-person instruction prior to COVID-19 and may return that way eventually. Therefore, there is a need to explore the strategies and perceptions of teachers in a classroom that is 100% in-person. All of the teachers in this study voiced opinions that favoured using ALEKS during the time of this study for several reasons related to COVID-19 and needing to provide remote instruction. However, if teachers were to have in-person interactions with their students every day, then the teaching strategies and perceptions of ease of use and usefulness might be different.

Another area that future research could explore is in a mixed-methods study to try to connect test scores or survey data to the experiences of teachers or students. Several studies related to ALEKS have attempted to measure the academic performance of students using test results. Some of them have shown favourable results (Goodwin, 2017; Karner, 2016; Yilmaz, 2017) and some have shown mixed results (Mills, 2018; Nwaogu, 2012; Richard, 2019). There have been a limited number of studies that have attempted to connect the teaching strategies used with ALEKS to test scores (Benjamin, 2020; Padilla-Oviedo et al., 2016; Wang et al., 2018). Significant research has been done on effective teaching strategies used with technology (Murphy, 2016; De Witte & Rogge, 2014; Ra et al., 2016; Sen & Ay, 2017; Wachira & Keengwe, 2011). Future research could attempt to make the connection between how ALEKS is used for instruction in a mathematics classroom and its impact on academic achievement.

This study collected qualitative data on the experiences of teachers using ALEKS through interviews. This study indicates several teaching strategies used by high school mathematics teachers with ALEKS, as well as the ways they find the tool to be easy to use and useful. Future research could collect from a larger sample of teachers and make use of survey data to gain a better understanding of the use of ALEKS. Using surveys to collect data about the experiences of teachers could also allow for comparisons to be made across participants in terms of the experience level of teachers, support from administration, and other factors that have shown evidence of positively impacting teaching with technology (Goos & Bennison, 2008; Pierce & Ball, 2009; Wachira & Keengwe, 2011).

One of the limitations of this study was that it relied on the data collected from first-hand interviews with teachers. Future research could explore collecting data concerning how ALEKS is used through students' voices or classroom observations. No attempt was made in this study to collect input from the students in these classrooms, nor has much research been conducted that has attempted to analyze the voices of students using ALEKS (Serhan, 2017; Wang et al., 2018; Xu et al., 2009). Since the students are the ones who are using the tools in ALEKS, their opinions and perceptions could offer insight into how the tool is used and how useful it is to their learning. This study also relied on teachers being honest and forthcoming in their interviews about their experiences using ALEKS. Future studies could make use of observations or survey data from students to confirm that the information presented in interviews is consistent with what is happening in class.

This section offers several recommendations for future research to be conducted on the teaching strategies and perceptions of ease of use and usefulness of ALEKS. Future studies could attempt to enhance the scope of the study by extending it to more teachers, a more diverse set of classroom environments or other adaptive learning tools. Researchers could also make use of other data-collection methods by using surveys, observations, and interviews with other stakeholders to gain a wider array of sources. Much of the previous research related to ALEKS has measured academic performance in connection to use of the tool but without actually collecting information on how the tool is used by teachers. Future studies could attempt to make a connection between teaching strategies used with ALEKS and academic achievement.

Chapter 5 Summary

The purpose of this study was to understand what teaching strategies high school mathematics teachers used with the ALEKS system and to examine their perceptions of its ease of use and usefulness. This study followed a basic qualitative design. Five high school mathematics teachers were interviewed three times throughout an academic school year, and their responses were collected, organized, and analyzed. Findings about the research questions were discussed by connecting them to the existing literature related to teaching strategies, adaptive learning tools, and the use of technology in mathematics classrooms.

This study could have several implications for future research related to adaptive learning tools and also helps to fill the gaps in the research related to ALEKS by providing the voices of the teachers. Many stakeholders could benefit from the findings of this study. Teachers and schools could use this study when deciding whether or not to use ALEKS, when deciding what teaching strategies they could implement with it, when deciding which tools could be useful for them, and when deciding what professional development and training would be needed. ALEKS and similar technology companies could benefit from the findings of this study by making improvements to their product or to the way they suggest it be used in high school mathematics classrooms.

This study took place over the course of one academic year with five high school mathematics teachers from the Chicagoland area. Given that the scope of this study was a small group of teachers from a specific geographic area, there are limitations and assumptions to be considered. This study did not attempt to analyze background teachers had with ALEKS in terms of their level of confidence or training. This may have impacted the ways teachers used the tool or their perceptions of its ease of use or usefulness. Interviews were the primary source of data collection, so this study relied on the teachers being honest and open with their descriptions of how they used ALEKS during the course of this study. Although the first interviews were coded independently by the researcher and his advisor, a significant number of the codings were conducted solely by the researcher. His assumptions and bias may have influenced how interviews were coded.

This study attempted to understand what teaching strategies high school mathematics teachers used with the ALEKS system and to examine their perceptions of its ease of use and usefulness. Recommendations for future research could enhance the scope of this study by including more teachers and a more diverse set of geographic locations. This study also relied on interview data. Future studies could also make use of other data collection methods like surveys, observations, and interviews with other stakeholders. Although this study attempted to collect the voices of teachers using ALEKS, students are the ones primarily using the tool. Future studies could attempt to collect information from students about their perceptions of using ALEKS. Much of the research related to ALEKS has attempted to measure academic performance using the tool, but fails to connect outcomes to teaching strategies used with the tool. Future studies could attempt to bridge the gap between teaching strategies used with ALEKS and academic achievement.

REFERENCES

ACT (2009). Connecting College Readiness Standards to The Classroom for Mathematics Teachers. Retrieved from http://www.successlineinc.com/actinfo/collegereadinessstandardstoclassroom/explore/explore_math.pdf

ALEKS (2020a, July 22). Implementation strategies. Retrieved from https://www.aleks.com/k12/K12_Implementation_Strategies.pdf

ALEKS (2020b, July 22). Overview of ALEKS. Retrieved from https://www.aleks.com/about_aleks/overview

ALEKS (2020c, July 22). Teaching with ALEKS for K-12 education. Retrieved from https://www.aleks.com/manual/pdf/teaching-k12.pdf

ALEKS (2020d, July 22). What is ALEKS. Retrieved from https://www.aleks.com/about_aleks

ALEKS (2021e, March 31). Instructor's Manual for Higher Education Mathematics. Retrieved from https://www.aleks.com/manual/pdf/educators-highedmath.pdf

ALEKS (2021f, March 31). New ALEKS Student Module Reference Guide. Retrieved from https://www.aleks.com/highered/math/New_ALEKS_Student_Module_Reference_Guide.pdf

Anney, V. N. (2014). Ensuring the quality of the findings of qualitative research: Looking at trustworthiness criteria. *Journal of Emerging Trends in Educational Research and Policy Studies, 5*(2), 272-281.

Anthony, G., & Walshaw, M. (2009). Characteristics of effective teaching of mathematics: A view from the West. *Journal of Mathematics Education*, *2*(2), 147-164.

Arends, F., Winnaar, L., & Mosimege, M. (2017). Teacher classroom practices and Mathematics performance in South African schools: A reflection on TIMSS 2011. *South African Journal of Education*, *37*(3), 1-11.

Attali, Y., & van der Kleij, F. (2017). Effects of feedback elaboration and feedback timing during computer-based practice in mathematics problem solving. *Computers & Education*, *110*, 154-169.

Azevedo, R., Cromley, J. G., Winters, F. I., Moos, D. C., & Greene, J. A. (2005). Adaptive human scaffolding facilitates adolescents’ self-regulated learning with hypermedia. *Instructional Science*, *33*(5), 381-412.

Baker, R. S., D'Mello, S., Rodrigo, M. T., & Graesser, A. (2010). Better to be frustrated than bored: The incidence, persistence, and impact of learners' cognitive-affective states during interactions with three different computer-based learning environments. *International Journal of Human-Computer Studies, 68*(4), 223-241.

Barrett, G. (2018). *Mission accepted: A case study examining the relationship of Khan Academy with student learning* (Unpublished doctoral dissertation). University of Oregon, Eugene, Oregon.

Barry, V. J. (2008). Using descriptive feedback in a sixth grade mathematics classroom. *Action Research Projects, 9*(1), 1-49.

Bartell, T., Wager, A., Edwards, A., Battey, D., Foote, M., & Spencer, J. (2017). Toward a framework for research linking equitable teaching with the standards for mathematical practice. *Journal for Research in Mathematics Education*, *48*(1), 7-21.

Beal, C. R., Arroyo, I. M., Cohen, P. R., & Woolf, B. P. (2010). Evaluation of AnimalWatch: An intelligent tutoring system for arithmetic and fractions. *Journal of Interactive Online Learning*, *9*(1), 64-77.

Bebell, D., & O’Dwyer, L. (2010). Educational outcomes and research from 1:1 computer settings. *The Journal of Technology, Learning and Assessment, 9*(1), 1-15.

Benjamin, R. J. (2020). *Perceptions of Adaptive Technology Usage in Secondary Math Classrooms* (Doctoral dissertation). Lynn University, Boca Raton, FL.

Bochniak, J. S. (2014). The Effectiveness of Computer-Aided Instruction on Math Fact Fluency (Doctoral dissertation). Walden University, Minneapolis, MN.

Bray, A., & Tangney, B. (2017). Technology usage in mathematics education research–A systematic review of recent trends. *Computers & Education*, *114*(1), 255-273.

Bulger, M. (2016). Personalized learning: The conversations we're not having. *Data and Society*, *22*(1), 1-29.

Burns, M. K., Kanive, R., & DeGrande, M. (2012). Effect of a computer-delivered math fact intervention as a supplemental intervention for math in third and fourth grades. *Remedial and Special Education*, *33*(3), 184-191.

Caelli, K., Ray, L., & Mill, J. (2003). 'Clear as mud': toward greater clarity in generic qualitative research. *International Journal of Qualitative Methods*, *2*(2), 1-13.

Campuzano, L., Dynarski, M., Agodini, R., & Rall, K. (2009). Effectiveness of reading and mathematics software products: Findings from two student cohorts. In NCEE 2009-4041 (4041). Washington D.C.: National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education.

Cardino Jr, J. M., & Cruz, R. A. O. D. (2020). Understanding of learning styles and teaching strategies towards improving the teaching and learning of mathematics. *LUMAT: International Journal on Math, Science and Technology Education*, *8*(1), 19-43.

Caro, D. H., Lenkeit, J., & Kyriakides, L. (2016). Teaching strategies and differential effectiveness across learning contexts: Evidence from PISA 2012. *Studies in Educational Evaluation*, *49*, 30-41.

Cheung, A. C., & Slavin, R. E. (2013). The effectiveness of educational technology applications for enhancing mathematics achievement in K-12 classrooms: A meta-analysis. *Educational Research Review*, *9*(1), 88-113.

Chu, L., Nautiyal, A., Rais, S., & Yamtich, H. (2018). Does Khan Academy Work?. Retrieved from https://www.ischool.berkeley.edu/sites/default/files/sproject_attachments/w241_final_report_does_khan_work.pdf

Clark, R. E. (1994). Media will never influence learning. *Educational Technology Research and Development*, *42*(2), 21-29.

Corbett, A. T., & Anderson, J. R. (2001, March). Locus of feedback control in computer-based tutoring: Impact on learning rate, achievement and attitudes. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 245-252).

Craig, S. D., Hu, X., Graesser, A. C., Bargagliotti, A. E., Sterbinsky, A., Cheney, K. R., & Okwumabua, T. (2013). The impact of a technology-based mathematics after-school program using ALEKS on student's knowledge and behaviors. *Computers & Education*, *68*(1), 495-504.

Creswell, J. W. & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches.* (5th Ed.). Thousand Oaks, CA: SAGE.

Creswell, J. W. & Poth, C.N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). Thousand Oaks, CA: Sage.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, *13*(1), 319-340.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: a comparison of two theoretical models. *Management Science*, *35*(8), 982-1003.

Davis, F. D., & Venkatesh, V. (1996). A critical assessment of potential measurement biases in the technology acceptance model: three experiments. *International Journal of Human-Computer Studies*, *45*(1), 19-45.

Davis, M. R. (2019, May 14). *K-12 districts wasting millions by not using purchased software, new analysis finds*: Retrieved from https://marketbrief.edweek.org/marketplace-k-12/unused-educational-software-major-source-wasted-k-12-spending-new-analysis-finds/

Demana, F., & Waits, B. K. (2000). Calculators in mathematics teaching and learning. *Learning Mathematics For a New Century*, *51*(1), 1-16.

De Witte, K., & Rogge, N. (2014). Does ICT matter for effectiveness and efficiency in mathematics education?. *Computers & Education*, *75*(1), 173-184.

Elliott, V. (2018). Thinking about the coding process in qualitative data analysis. *The Qualitative Report, 23*(11), 2850–2861.

Elo, S., Kääriäinen, M., Kanste, O., Pölkki, T., Utriainen, K., & Kyngäs, H. (2014). Qualitative content analysis: A focus on trustworthiness. *SAGE Open*, *4*(1), 1-10.

Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & education*, *59*(2), 423-435.

Estrada, L. M., & Koolen, M. (2018). Audiovisual media annotation using qualitative data analysis software: A comparative analysis. *The Qualitative Report, 23*(13), 40–60.

Evers, J. C. (2011). From the past into the future. How technological developments change our ways of data collection, transcription and analysis. *FORUM: Qualitative Social Research, 12*(1), 1–31.

Falmagne, J. C., Cosyn, E., Doignon, J. P., & Thiéry, N. (2006). The assessment of knowledge, in theory and in practice. In *Formal concept analysis* (pp. 61-79). Springer, Berlin, Heidelberg.

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

Fang, Y., Ren, Z., Hu, X., & Graesser, A. C. (2019). A meta-analysis of the effectiveness of ALEKS on learning. *Educational Psychology*, *39*(10), 1278-1292.

Foshee, C. M., Elliott, S. N., & Atkinson, R. K. (2016). Technology-enhanced learning in college mathematics remediation. *British Journal of Educational Technology, 47*(5), 893–905.

Fossey, E., Harvey, C., McDermott, F., & Davidson, L. (2002). Understanding and evaluating qualitative research. *Australian & New Zealand Journal of Psychiatry*, *36*(6), 717-732.

Gemin, B., Pape, L., Vashaw, L., & Watson, J. (2015). Keeping pace with K-12 digital learning: An annual review of policy and practice. *Evergreen Education Group*.

Gilakjani, A. P., Lai-Mei, L., & Ismail, H. N. (2013). Teachers' use of technology and constructivism. *International Journal of Modern Education and Computer Science*, *5*(4), 49-63.

Goodwin, M. E. (2017, August). Using a Math Tutorial Program to Decrease the Number of Failed Grades the First Semester helping the College achieve a 91% First Year Retention Rate. In *2017 FYEE Conference*.

Goos, M., & Bennison, A. (2008). Surveying the technology landscape: Teachers' use of technology in secondary mathematics classrooms. *Mathematics Education Research Journal*, *20*(3), 102-130.

Griff, E. R., & Matter, S. F. (2013). Evaluation of an adaptive online learning system. *British Journal of Educational Technology*, *44*(1), 170-176.

Haelermans, C., & Ghyseld, J. (2013). *The effect of an individualized online practice tool on math performance-evidence from a randomized field experiment*. TIER Working Paper.

Hannafin, R. D., & Foshay, W. R. (2008). Computer-based instruction's (CBI) rediscovered role in K-12: An evaluation case study of one high school's use of CBI to improve pass rates on high-stakes tests. *Educational Technology Research and Development*, *56*(2), 147-160.

Hattie, J. A. (1999, August 2). Influences on student learning. Inaugural lecture, University of Auckland, New Zealand. Retrieved from http://geoffpetty.com/wp-content/uploads/2012/12/Influencesonstudent2C683.pdf

Hattie, J. (2012). *Visible learning for teachers: Maximizing impact on learning*. New York, NY: Routledge.

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of educational research*, *77*(1), 81-112.

Havnes, A., Smith, K., Dysthe, O., & Ludvigsen, K. (2012). Formative assessment and feedback: Making learning visible. *Studies in Educational Evaluation*, *38*(1), 21-27.

Hollands, F. M., & Pan, Y. (2018). Evaluating digital math tools in the field. *Middle Grades Review*, *4*(1), 1-16.

Hsieh, T.-C., Lee, M.-C. L., & Su, C.-Y. (2013). Designing and implementing a personalized remedial learning system for enhancing the programming learning. *Journal of Educational Technology & Society, 16*(4), 32–46.

Hsu, H. H., & Chang, Y. Y. (2013). Extended TAM model: Impacts of convenience on acceptance and use of Moodle. *Online Submission, 3*(4), 211-218.

IXL (2020, July 22). How IXL supports every learner. Retrieved from https://www.ixl.com/#experience

Johnson, L., Becker, S. A., Cummins, M., Estrada, V., Freeman, A., & Hall, C. (2016). *NMC horizon report: 2016 higher education edition*. Austin, TX: The New Media Consortium. Retrieved from https://www.sconul.ac.uk/sites/default/files/documents/2016-nmc-horizon-report-he-EN-1.pdf

Jones, S., & Latzko-Toth, G. (2017). Out from the PLATO cave: uncovering the pre-Internet history of social computing. *Internet Histories*, *1*(1-2), 60-69.

Kahlke, R. M. (2014). Generic qualitative approaches: Pitfalls and benefits of methodological mixology. *International Journal of Qualitative Methods*, *13*(1), 37-52.

Karatas, I., Tunc, M. P., Yilmaz, N., & Karaci, G. (2017). An investigation of technological pedagogical content knowledge, self-confidence, and perception of pre-service middle school mathematics teachers towards instructional technologies. *Journal of Educational Technology & Society*, *20*(3), 122-132.

Karner, M. L. (2016). *An Analysis of the Effectiveness of ALEKS within a High School Mathematics Setting* (Doctoral dissertation). Aurora University, Aurora, IL.

Kelly, D., & Rutherford, T. (2017). Khan Academy as supplemental instruction: A controlled study of a computer-based mathematics intervention. *The International Review of Research in Open and Distributed Learning*, *18*(4), 70-77.

Kelly, S. (2018). *The Impact of Khan Academy Math Remediation on Ninth Grade Student Achievement* (Unpublished doctoral dissertation). Liberty University, Lynchburg, VA.

Khan Academy (2020, July 22). Why Khan Academy works. Retrieved from https://www.khanacademy.org/

King, W. R., & He, J. (2006). A meta-analysis of the technology acceptance model. Information & management, 43(6), 740-755.

Knox, S., & Burkard, A. W. (2009). Qualitative research interviews. *Psychotherapy Research*, *19*(4-5), 566-575.

Kopcha, T. J. (2012). Teachers' perceptions of the barriers to technology integration and practices with technology under situated professional development. *Computers & Education*, *59*(4), 1109-1121.

Kulik, J. A., & Fletcher, J. D. (2016). Effectiveness of intelligent tutoring systems: A meta-analytic review. *Review of Educational Research, 86*(1), 42-78.

Kynigos, C. (2019). Adaptive Learning in Mathematics: Situating Multi Smart Øving in the Landscape of Digital Technologies for Mathematics Education. SLATE Research Report 2019-3, Bergen, Norway: Centre for the Science of Learning & Technology (SLATE). ISBN: 978-82-93789-00-0

Legewie, N., & Nassaurer, A. (2018). YouTube, Google, Facebook: 21st century online video research and research ethics. *Qualitative Social Research 19*(3), 1-22.

Levin, T., & Wadmany, R. (2006). Teachers' beliefs and practices in technology-based classrooms: A developmental view. *Journal of research on technology in education*, *39*(2), 157-181.

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

Light, D., & Pierson, E. (2014). Increasing student engagement in math: The use of khan academy in Chilean classrooms. *International Journal of Education and Development Using ICT*, *10*(2), 103-119.

Lincoln, YS. & Guba, EG. (1985). Naturalistic Inquiry. Newbury Park, CA: Sage Publications. (pp. 289-331).

Liu, M., McKelroy, E., Corliss, S. B., & Carrigan, J. (2017). Investigating the effect of an adaptive learning intervention on students' learning. *Educational Technology Research and Development, 65*(6), 1605-1625.

Longnecker, R. W. (2013). *IXL.com—measuring the effects of internet-based math instruction on the math achievement of middle school students* (Doctoral dissertation). Trevecca Nazarene University, Nashville, TN.

Marzano, R. J., Pickering, D., & Pollock, J. E. (2001). *Classroom instruction that works: Research-based strategies for increasing student achievement*. Ascd.

Math Space (2020, July 22). Math space: Our mission. Retrieved from https://mathspace.co/us/about-us

May, K. A. (1991). Interview techniques in qualitative research: Concerns and challenges. In J. M. Morse (Ed.), Qualitative nursing research: A contemporary dialogue (Rev. ed) (pp. 188-201). Thousand Oaks, CA: Sage.

McCulloch, A. W., Hollebrands, K., Lee, H., Harrison, T., & Mutlu, A. (2018). Factors that influence secondary mathematics teachers' integration of technology in mathematics lessons. *Computers & Education*, *123*(1), 26-40.

Means, B., Toyama, Y., Murphy, R., & Baki, M. (2013). The effectiveness of online and blended learning: A meta-analysis of the empirical literature. *Teachers College Record, 115*(3), 1-47.

Merriam, S. B. & Tisdell, E. J. (2016). Qualitative research: A guide to design and implementation (4th Ed.). San Francisco, CA: Jossey Bass.

Miles, M. B., Huberman, A. M., & Saldana, J. (2020). *Qualitative data analysis: A methods sourcebook* (4th ed.). SAGE.

Mills, N. (2018). *ALEKS constructs as predictors of high School mathematics achievement for struggling students* (Unpublished doctoral dissertation, Walden University, Minneapolis, MN).

Molnar, M. (2017, July 14). *Adaptive learning products gain ground in K-12, market survey finds.* Retrieved from https://marketbrief.edweek.org/fundamentals/adaptive-learning-products-gain-ground-k-12-market-survey-finds/?cmp=eml-enl-ii-news2

Monaghan, J. (2004). Teachers' activities in technology-based mathematics lessons. *International Journal of Computers for Mathematical Learning*, *9*(3), 327-357.

Mugo, D. G., Njagi, K., Chemwei, B., & Motanya, J. O. (2017). The technology acceptance model (TAM) and its application to the utilization of mobile learning technologies. *Journal of Advances in Mathematics and Computer Science*, *20*(4), 1-8.

Murphy, D. (2016). A Literature Review: The Effect of Implementing Technology in a High School Mathematics Classroom. *International Journal of Research in Education and Science*, *2*(2), 295-299.

Murray, M. C., & Pérez, J. (2015). Informing and Performing: A Study ComparingAdaptive Learning to Traditional Learning. *Informing Science: The International Journal of an Emerging Transdiscipline*, *18(1),* 111.

National Council of Teachers of Mathematics. (2020a, July 10). A Teacher's Guide to Reasoning and Sense Making. Retrieved from https://www.nctm.org/uploadedFiles/Standards_and_Positions/Focus_in_High_School_Mathematics/FHSM_TeacherGuide.pdf

National Council of Teachers of Mathematics. (2020b, July 10). Focus in High School Mathematics: Reasoning and Sense Making. Retrieved from https://www.nctm.org/uploadedFiles/Standards_and_Positions/Focus_in_High_School_Mathematics/FHSM_Executive_Summary.pdf

National Council of Teachers of Mathematics. (2020c, July 10). Principles to Actions Executive Summary. Retrieved from https://www.nctm.org/uploadedFiles/Standards_and_Positions/PtAExecutiveSummary.pdf

Nwaogu, E. (2012). *The effect of ALEKS on students' mathematics achievement in an online learning environment and the cognitive complexity of the initial and final assessments.* (Unpublished doctoral dissertation, Georgia State University, Atlanta, GA).

O'Cathain, A., Murphy, E., & Nicholl, J. (2010). Three techniques for integrating data in mixed methods studies. *BMJ, 341*.

Ortlipp, M. (2008). Keeping and using reflective journals in the qualitative research process. *The Qualitative Report*, *13*(4), 695–705. Retrieved from https://nsuworks.nova.edu/tqr/vol13/iss4/8/

Oxman, S., Wong, W., & Innovations, D. V. X. (2014). White paper: Adaptive learning systems. *Integrated Education Solutions*. Retrieved from http://kenanaonline.com/files/0100/100321/DVx_Adaptive_Learning_White_Paper.pdf

Padilla-Oviedo, A., Mundy, M. A., & Kupczynski, L. (2016). The Effects of Instructional Strategies, College Division, and Gender on Students' Performance in Elementary Statistics and Probability at a University in South Texas. *FOCUS on Colleges, Universities & Schools*, *10*(1).

Peshek, S. (2012). Assessment and grading in a differentiated mathematics classroom. *Ohio Journal of School Mathematics. 65*(1), 45-50.

Pierce, R., & Ball, L. (2009). Perceptions that may affect teachers' intention to use technology in secondary mathematics classes. *Educational Studies in Mathematics*, *71*(3), 299-317.

Pilli, O. (2008). *The effects of computer-assisted instruction on the achievement, attitudes, and retention of fourth grade mathematics course* (Unpublished doctoral dissertation, University of Middle East Technical, Ankara, Turkley).

Punch, K. F. (2013). *Introduction to social research: Quantitative and qualitative approaches*. Thousand Oaks, CA: Sage.

Qu, S. Q., & Dumay, J. (2011). The qualitative research interview. *Qualitative Research in Accounting & Management*, *8*(3), 238-264

Ra, S., Chin, B., Lim, C. P. (2016). A holistic approach towards iInformation and Communication Technology (ICT) for addressing educational challenges in Asia and the Pacific. *Educational Media International, 53*(2), 69-84

Rakes, G. C., Fields, V. S., & Cox, K. E. (2006). The influence of teachers' technology use on instructional practices. *Journal of Research on Technology in Education*, *38*(4), 409-424.

Richard, V. M. (2019), Exploring the link between students' usage of ALEKS and their performance on state benchmark assessments in mathematics (Unpublished doctoral dissertation, Louisiana State University, Baton Rouge, LA).

Roberts-Mahoney, H., Means, A. J., & Garrison, M. J. (2016). Netflixing human capital development: Personalized learning technology and the corporatization of K-12 education. *Journal of Education Policy*, *31*(4), 405-420.

Rogers, P. L. (2000). Barriers to adopting emerging technologies in education. *Journal of Educational Computing Research*, *22*(4), 455-472.

Roschelle, J., Rafanan, K., Bhanot, R., Estrella, G., Penuel, B., Nussbaum, M., & Claro, S. (2010). Scaffolding group explanation and feedback with handheld technology: Impact on students' mathematics learning. *Educational Technology Research and Development*, *58*(4), 399-419.

Ryan, F., Coughlan, M., & Cronin, P. (2007). Step-by-step guide to critiquing research. Part 2: Qualitative research. *British Journal of Nursing*, *16*(12), 738-744.

Sabo, K. E., Atkinson, R. K., Barrus, A. L., Joseph, S. S., & Perez, R. S. (2013). Searching for the two sigma advantage: Evaluating algebra intelligent tutors. *Computers in Human Behavior*, *29*(4), 1833-1840.

Sauro, J. (2019, May 7). *10 things to know about the technology acceptance model.* Retrieved from https://measuringu.com/tam/

Sen, C. & Ay, Z.S. (2017). The views of middle school mathematics teachers on the integration of science and technology in mathematics instruction. *International Journal of Research in Education and Science (IJRES), 3*(1), 151-170.

Seidman, I. (2006). *Interviewing as qualitative research: A guide for researchers in education and the social sciences*. New York, NY: Teachers College Press.

Serhan, D. (2017, March). Students' attitudes toward the use of adaptive learning systems in learning college algebra. In *Society for Information Technology & Teacher Education International Conference* (pp. 2005-2010). Association for the Advancement of Computing in Education (AACE).

Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research*, *78*(1), 153-189.

Shute, V. J., & Zapata-Rivera, D. (2012). Adaptive educational systems. *Adaptive Technologies for Training and Education*, *7*(27), 1-35.

Smeets, E. (2005). Does ICT contribute to powerful learning environments in primary education?. *Computers & Education*, *44*(3), 343-355.

Smith, K. (2018). Perceptions of preservice teachers about adaptive learning programs in K-8 mathematics education. *Contemporary Educational Technology*, *9*(2), 111-130.

Sugiura, L., Wiles, R., & Pope, C. (2017). Ethical challenges in online research: Public/private perceptions. *Research Ethics, 13*(3-4), 184–199.

Sun, Z., Xie, K., & Anderman, L. H. (2018). The role of self-regulated learning in students' success in flipped undergraduate math courses. *The internet and higher education*, *36*(1), 41-53.

Taagepera, M., & Noori, S. (2000). Mapping students' thinking patterns in learning organic chemistry by the use of knowledge space theory. *Journal of Chemical Education*, *77*(9), 1224-1229.

Tomlinson, C. A., Moon, T. R., & Imbeau, M. B. (2013). *Assessment and student success in a differentiated classroom* [White Paper]. ASCD. https://www.teachsoutheast.co.uk/assets/documents/nqt/nqt6/assessment-and-di-whitepaper.pdf

Tracy, S. J. (2010). Qualitative quality: Eight "big-tent" criteria for excellent qualitative research. *Qualitative Inquiry, 16*(10), 837–851.

VanLehn, K. (2011). The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems. *Educational Psychologist*, *46*(4), 197-221.

Venkatesh, V., & Davis, F. D. (1996). A model of the antecedents of perceived ease of use: Development and test. *Decision Sciences*, *27*(3), 451-481.

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management science*, *46*(2), 186-204.

Verdinelli, S., & Scagnoli, N. I. (2013). Data display in qualitative research. *International Journal of Qualitative Methods, 12*(1), 359–381.

Wachira, P., & Keengwe, J. (2011). Technology integration barriers: Urban school mathematics teachers perspectives. *Journal of Science Education and Technology*, *20*(1), 17-25.

Wang, G., Tang, Y., Li, J., & Hu, X. (2018, June). Modeling student learning behaviors in ALEKS: A two-layer hidden Markov modeling approach. *Artificial Intelligence in Education, 10948*(1*),* 374-*378).*

Watt, D. (2007). On becoming a qualitative researcher: The value of reflexivity. *The Qualitative Report*, *12*(1), 82–101. Retrieved from https://nsuworks.nova.edu/tqr/vol12/iss1/5/

Wenglinsky, H. (2002). The link between teacher classroom practices and student academic performance. *Education Policy Analysis Archives*, *10*(12), 1-30.

Winters, F. I., Greene, J. A., & Costich, C. M. (2008). Self-regulation of learning within computer-based learning environments: A critical analysis. *Educational Psychology Review*, *20*(1), 429-444.

Woods, T. (2017). *Analysis of ALEKS mathematics placement test data.* (Doctoral dissertation). Michigan Technological University, Houghton, Michigan.

Xu, Y. J., Meyer, K. A., & Morgan, D. D. (2009). A mixed-methods assessment of using an online commercial tutoring system to teach introductory statistics. *Journal of Statistics Education*, *17*(2), 1-17.

Yilmaz, B. (2017). *Effects of adaptive learning technologies on math achievement: A quantitative study of aleks math software* (Unpublished doctoral dissertation, University of Missouri, Kansas City, MO).

Yousafzai, S. Y., Foxall, G. R., & Pallister, J. G. (2007). Technology acceptance: a meta-analysis of the TAM: Part 2. *Journal of Modelling in Management*, *2*(3), 281-304.

Ysseldyke, J., & Tardrew, S. (2007). Use of a progress monitoring system to enable teachers to differentiate mathematics instruction. Journal of Applied School Psychology, 24(1), 1–28.

Zengin, Y. (2017). Investigating the use of the Khan Academy and mathematics software with a flipped classroom approach in mathematics teaching. *Journal of Educational Technology & Society*, *20*(2), 89-100.

Zimmer, T. (2014, October 22). *Re-thinking higher ed: A case for adaptive learning.* Retrieved from http://www.forbes.com/sites/ccap/2014/10/22/rethinking-higher-ed-a-case-for-adaptivelearning/

APPENDIX A

Interview Questions Round 1

1) What classes are you teaching this year, what classes you're using Aleks, and what's the grade level of those classes this year?

2) Did you receive any training on ALEKS, or how did you learn how to use the tool?

3) During this school year, what teaching strategies did you plan to use with ALEKS in your mathematics classroom?

4) Would you please give me an example of an activity/content you are planning that involves the use of ALEKS?

5) What are your perceptions of how easy to use ALEKS was going to be as a tool this school year? Why do you think that?

6) What are your perceptions of how useful ALEKS was going to be as a tool this school year?

7) In specific ways did you envision ALEKS to be useful as a tool for your class this year?

APPENDIX B

Interview Questions Round 2

1) What teaching strategies have you used with the ALEKS system in your classrooms this school year?

2) Please describe a lesson or content where you have used this tool.

3) Was it successful? How do you know?

4) Please describe how you have used it to assist with instruction during class time.

5) Please describe how you use ALEKS to assess students and provide feedback.

6) How easy has it been to use ALEKS for teaching your mathematics class?

7) How useful has ALEKS been for you to deliver instruction?

8) How useful has ALEKS been to assess student work?

9) Describe a specific situation in which ALEKS was useful in your teaching?

10) What specifically is useful about using ALEKS in a remote setting?

Additional Questions for Each Participant

Steve
Can you provide any specific examples of how you use ALEKS to analyze data?

Tony
Do you use ALEKS to personalize or differentiate? If so, could you provide specific examples?

Bruce
Do you use ALEKS to personalize or differentiate? If so, could you provide specific examples?

Can you provide any specific examples of how you use ALEKS to analyze data?

Donald
Do you use ALEKS to assess student learning? If so, can you provide specific examples?

APPENDIX C

Interview Questions Round 3

1) Looking back at your use of ALEKS throughout the school year, describe how you used ALEKS in your teaching this year in terms of providing instruction.

2) In reflecting on how you used ALEKS for instruction, how would you describe its effectiveness?

3) Looking back at your use of ALEKS throughout the school year, describe how you used ALEKS in your teaching this year in terms of assessing students and providing feedback.

4) In reflecting on how you used ALEKS for assessment and feedback, how would you describe its effectiveness?

5) Based on your experience using ALEKS this year, how do you anticipate using ALEKS in the future? What aspects of instruction, feedback, assessment, etc. would you like to continue to use?

6) How would you use the tool differently? Why would you make this change?

7) If you were to see students in class everyday, then would this change the way you would ALEKS? If so, then how would your use of the tool differ?

7) Reflecting on all of the ways you have used ALEKS, how easy ALEKS was to use for teaching your class?

8) If you have any new ways you would like to use ALEKS in the future, comment on how easy you anticipate it will be for you to do so?

9) Reflecting on your experience this school year, which ALEKS tools do you perceive were the most useful?

10) Due to the remote learning setting, comment on how useful you found ALEKS to be compared to your experience in the past.

11) Perceptions of how it might be different - if stay the same or differently - why you might do that. What would you continue to do? - Why would you keep doing that?

APPENDIX D

Comparison of Teaching Strategies with ALEKS Among Participants

	Steve	**Tony**	**Bruce**	**Natasha**	**Donald**
Assessment & Grading	ALEKS Quizzes as part of an assessment Bonus points given for working ahead	Placement tests given throughout year to measure growth Submitting work with ALEKS assessments to compare score with work	End of unit assessments using ALEKS Assessments done within certain time frame of classroom instruction	End of unit assessments using ALEKS Formative and summative assessments	ALEKS assessments of objectives Video recording explanation of ALEKS topic from their learning path
Goal Setting	Assigns weekly objectives for students to work on Goal is to do 10 topics per week and offers incentive to do additional topics	Assign a minimum of 1 hour per week outside of class time Hoping to see growth from first placement test to the second test	Competencies for students to master throughout the year Percentage goals of course completion based on time left in school year	No goal setting from teacher on the my path portion Weekly goals for objective completion assigned by the teacher	Weekly goal of three learning topics per week but students are welcome to work ahead

	Steve	Tony	Bruce	Natasha	Donald
Data Analysis	Detailed question report prior to class to select problems to review	Measures growth from placement tests on ALEKS against time spent working on the objectives Analyze pie chart of mastered topics, time spent on ALEKS, and gaps in learning to develop instruction	Uses initial pie chart to see where students are at Follows graphs to see where students are in their progress with the class Detailed question report to see what students are doing wrong	Checks reports on formative assessment to see progress on individual objectives before the summative assessment; uses to plan classroom activities	Checks data on completion and scoring to facilitate discussions with students Uses reports to see what students are doing well on and not doing well on Monitors progress on their students personal pie chart

	Steve	Tony	Bruce	Natasha	Donald
Feedback	Uses reports to determine feedback students need based on performance on assignments Relies on ALEKS feedback because it does more than provide right/wrong, but also a “map” to learn a topic	Provides feedback for students on growth from placement test to placement test Uses pie chart to recommend topics where students were struggling Gives individual feedback and practice on ALEKS objectives where students struggled	Views ALEKS data features with students to have discussions with students about using the ALEKS My Path to help them in class Acts as a coach with student reflection Gives content specific feedback to students based on data in the question reports	Relies on ALEKS to give the immediate response feedback Uses the question reports as formative assessment to provide remediation Provides feedback to student questions based on feedback they received from ALEKS	Makes additional lessons or videos based on the struggles seen in ALEKS reports Students use immediate feedback from ALEKS in form of explanations and tutorials For live instruction, give individual instruction and support

	Steve	Tony	Bruce	Natasha	Donald
Individual Pathway	Does not use the ALEKS My Path portion as part of class Uses individual report to identify student struggles	Students assigned topics based on the initial assessment, student could choose topics to work on After 2nd assessment teacher recommended specific topics for students to work on in the individual pathway	Students are assigned weekly objectives that they can work on at their own pace ALEKS My Path to follow progress based on percentage completed	Encourages student use of the ALEKS Math Path portion for individualized learning, but does not assign goals or grades to it Students do practice problems on ALEKS My Path to supplement work as a prerequisite skill building	Uses the ALEKS My Path throughout year with a set number of topics to complete per week with a video explanation of one of the topics Topics based on the initial knowledge check

	Steve	**Tony**	**Bruce**	**Natasha**	**Donald**
In-Class ALEKS Instruction	Warm-ups and entrance slips of topics students are struggling with based on data analysis features in ALEKS	Bell ringers or entrance slips of ALEKS problems If additional time in class, student pull up ALEKS to work on their individualized pathway and teacher gives assistance and feedback	Students use ALEKS individually while teacher can provide instruction to other small groups or individuals Do-Nows, exit slips, pulls up preview mode in ALEKS to go over technology issues	Pulls up student view to review problems based on student questions or issues based on data analysis	Students present screens so teacher can give feedback In class students are working on ALEKS and teacher is giving real time feedback and instruction to students
Initial Assessment	Did an initial assessment, but did not use the individualized pathway for students	Used the initial assessment to get a baseline of where students were at the beginning of the school year to compare to future assessments	Used initial assessment to see where students are and so that students could test out of certain objectives	Students took the initial assessment so they could have the my path set up, but it is not required for the course for students to complete topics outside of the assigned objectives	Starts year with initial assessment to set up my path for students

	Steve	Tony	Bruce	Natasha	Donald
Practice of Objectives	Assigns homework specific to the objectives being taught in class for student to do in ALEKS with multiple attempts	Students are sometimes required to complete an assignment and submit work for teacher as homework Uses a document for students to show work alongside ALEKS	Students complete ALEKS assignments in conjunction with the class objectives through formative assessments and homework	Homework assignments, practice for students, and a formative assessment tool	Assigns 24 learning objectives in ALEKS for students to master throughout the school year.

APPENDIX E

Comparison of Perceptions of Ease of Use Among Participants

	Ease of Use	Struggles/Needing Time	Limitations
Steve	Found it easy to use & user friendly Anticipates it to be easy to use in the future	Sometimes tough finding questions, need to know how ALEKS organizes topics Found math topics in several organizations in ALEKS, just need to get used to it	Wishes ALEKS could allow for instructor to write own question
Tony	Found it easy to use & navigate A lot easier this year	Just needed time to work with ALEKS Getting more proficient in seeing what ALEKS has to offer and what I can see about individual students	Can't pick out the exact skills that the kids are working on in the My Path Limitations in what can be seen in a score
Bruce	Found it to be simple to work with & simple to find things	Struggled a little at beginning, but improved with some help Found it to be a little overwhelming because of the amount offered in ALEKS	Difficult for students to use with iPads from a technical standpoint Student don't read little details on the directions ALEKS provides and ALEKS doesn't accept multiple forms of answers
	Ease of Use	**Struggles/Needing Time**	**Limitations**
Natasha	Found it easy to use, easy to find objectives to assign, and easy to pull up information	None	None

Donald	Would not describe it easy, but not difficult to use either No more challenging than any other platform	Did not think it was very intuitive	Wishes the program offered more control with assignments

APPENDIX F

Comparison of Perceptions of Usefulness Among Participants

	Steve	**Tony**	**Bruce**	**Natasha**	**Donald**
ALEKS Instructional Tools	ALEKS instruction is powerful and has sticking power Does a great job of asking questions that show reasoning conceptual understanding	Students like the tutorials that ALEKS provides ALEKS constantly revisits topics Tool gets easier for students as they complete more knowledge checks	Useful that everything is all in one place, especially for students having trouble	Option to add extra tools and time to assessment Looking at the solutions to missed questions, being able to pull up the problems	Ability for students to be able to click a button and get help right away with an explanation Accessibility is very useful and powerful as a teacher Keeps time of how long students are using the tool

	Steve	Tony	Bruce	Natasha	Donald
Assessment Tools	Security for test taking Ability to add time to assessments Assessment questions allow teacher to see for conceptual understanding Provides feedback for teacher based on student responses Whole class analysis of where kids are	Ability to assign a proctored placement that is protected by a code Assessment breakdown of what a student knows and doesn't know Being able to see real time when kids are in ALEKS and breakdown of minutes that kids are actively engaged in ALEKS	The malleability of the assessments	Access to helps during assessments The reports that come with the assessments Different features with testing times Great tool for formative assessments Ability for students to do retakes	Easy to pull questions from learning standards All different questions minimizes copying and cheating Breakdowns of student frequency using the platform Preview feature of assessment questions

	Steve	**Tony**	**Bruce**	**Natasha**	**Donald**
Differentiation	Built in differentiation Giving kids as many questions as they need	The ability to see the mastery level of students to differentiate instruction	Helps with grouping students	Creating assignments tailored to specific students Adjusting assignments, deadlines, and assessment times	ALEKS systems allows for students to access topics that they feel are approachable Program meets students where they are
Feedback	ALEKS provides timely feedback to students Subtle feedback of knowing that an answer is right or wrong Analysis of student performance	Useful to drive conversations with students struggling, tutorials are helpful in providing feedback Can give feedback based on the amount of time spent on problems	Given the teacher great reflective conferences Helps to give students quick feedback on something	Immediate response feedback for students outside of the classroom Assessment tools with immediate feedback	Easy for students to click a button and get an explanation Students can do their work and get feedback whenever they would like

	Steve	Tony	Bruce	Natasha	Donald
Negative Perceptions	Can not assess procedural understanding outside of if the answer is right or wrong. ALEKS feedback to teacher is not specific enough where teacher can diagnose issues students may be having	He can't see specifically what questions the student is doing wrong Hard to plan lessons for whole class if using ALEKS	Lots of reading for students and the students struggle with technical terms "Math for math teachers and not math learner" Dealing with a machine at times can be frustrating; marking things wrong that are right Tiny directions on the way answers are written	In class students preferred interacting with each other compared to ALEKS Some minor issues with answer entry in ALEKS until students get used to it	Explanations can be challenging for students because of the reading level Students are not the best at reading the ALEKS explanations

	Steve	Tony	Bruce	Natasha	Donald
Personalization	The ability of ALEKS to allow students to advance to additional objectives The individual reports to get an idea of who is struggling and what they are struggling with	Uses the product for students to pick topics and follow the my path Success for the kids who take ownership/buy-in	Knowledge check to find gaps My path to help to provide feedback and do goal setting Allows kids to work at their own pace	Move on throughout the course without the need for a teacher to be present Customizable retakes of assessments in ALEKS	Breaks it down to what they are able to handle for the teacher Students like to choose their own topics when working ahead.
Question Generation	Generates multiple problems and examples that allows students to “fail into success” Some kids get 5 questions, some get 10, and some get 20 and that helps	ALEKS constantly revisits topics for students	Likes the question regeneration, but doesn’t work for every problem Helpful for student to work together and focus on the process		Since all of the students are getting different problems it is a more authentic way of learning the topics

	Steve	Tony	Bruce	Natasha	Donald
Remote Learning Usefulness	Work ahead on objectives given limited class time Multiple opportunities to answer the same question and receive feedback because they have less access to a teacher The timeliness of the feedback Secure assessments No longer a mystery of what is happening at home	Useful because they will only be seeing students for a few hours a week More useful this year compared to prior years Secure proctored tests	Stated that it has help a lot in the remote learning environment Has been able to help make individual connections with the work they have done	Really happy to be using ALEKS this year Immediate response feedback The ability for students to be able to test at anytime and that resources can be limited for those assessments Test on own time so class time can be used for lessons Allows them to practice anytime	Useful and helpful given the current circumstances Very helpful based on the capabilities of ALEKS

	Steve	**Tony**	**Bruce**	**Natasha**	**Donald**
Saving Time / Efficiency	Differentiation without having to do additional planning Expedite remediation for students so the teacher can focus on new material “Failing into success” in a more streamlined manner than worksheets through problem generation	Efficient in creating instruction items Very little planning needed on days where students use My Path		Students can test anytime with also limiting resources Making custom assessments so student can retake assessments faster Testing at home makes for better use of class time	

APPENDIX G

Comparison of Future Use of ALEKS Among Participants

	Steve	**Tony**	**Bruce**	**Natasha**	**Donald**
Future ALEKS Use	Similar to Current Usage	Using it in Class More	Use it the Same	Use it the Same	Keep thing the Same, Unless School Opens
Changes to ALEKS Use	More entrance/exit slips Weekly homework assignments	Use it more in class	More entrance and exit slips	Making greater use of the My Path for students	Dedicate days to work on their learning path

	Steve	Tony	Bruce	Natasha	Donald
Perceptions/ Rationale	Allowing students to push themselves without being overwhelmed Find more consistent ways to use it I can use the opportunity for differentiation Figure out ways to get students to ask more questions	Better job next year of monitoring the progress on it and talking them through it Make a connection to the next class Use it in class to describe the underlying purpose of ALEKS and how the system functions	Making more connections and doing more application problems	Give students more opportunities to work on their own	Communicating mathematics more regularly
Use if Return to School	Quick exit slips or warm ups Using ALEKS much more	Full 50 minute class periods Walking around to give feedback	Students working together on ALEKS problems	No different than how currently using	Dedicate one days to work on My Path