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ENGAGEMENT TIME AND PERSISTENT DEFICITS IN MATHEMATICS: UNDERSTANDING THE RELATIONSHIP BETWEEN INTELLIGENT TUTORING SYSTEMS AND THE ABILITY TO LEARN

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ABSTRACT

The acquisition of mathematical competencies presents unique learning hurdles to subpopulations of varied ability levels. Several pedagogically designed computer-based mediums attempt to address these issues. Research suggests computer-based mediums, such as intelligent tutoring systems (ITS), show an attrition of benefit with every year of academic growth. Outside of advanced course work, these mediums offer little to no instructional benefit for students at the secondary level. The derived condition places secondary-level students with persistent deficits in mathematics (PDM) in a detrimental learning condition.

Students with PDM mimic the learning difficulties seen in students' with mathematical learning disabilities (MLD) and their low-achieving (LA) peers. They present some of the mathematical difficulties seen with MLD, the inconsistent performance seen in their LA peers, along with poor performance over multiple years and outcome measures. The ubiquitous presentation of PDM inhibits the identification and remediation necessary to improve instructional outcomes. There is a significant gap in the literature on effective strategies and approaches to mathematical difficulties for secondary students and on the instructional variables influencing outcomes for these students. In consequence, the instructional demands of secondary education for students' with PDM leverages their future against their ability to learn.

This study sought to assess the efficacy of engagement time for students' with PDM as it pertains to the development of algebraic competency, while using Assessment and Learning in Knowledge Spaces (ALEKS), an ITS, as the medium of instruction. With this in mind, a cross-sectional analysis was done using 138 ninth-grade students, performing in the lowest quartile of performance, across three high schools using ALEKS as a part of their supplemental instruction to characterize the instructional effect of engagement time. This study controlled for gender, socioeconomic level, prior reading achievement, prior math achievement, and attendance. Measures of central tendency were used to identify correlations and make predictions about future performance. Results revealed that engagement showed no significant relationship with any curriculum-based measurement. However, they also revealed that students' with PDM showed incremental growth toward closing the achievement gap and that the number of skills mastered per hour was a greater predictor of future outcomes.

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To my amazing sons, Hunter and Tysen, remember which dog you feed,

and

To Mom, Dad, Linda, Lussandra, Xavier, Tiffany, and Kyle let the energy within continue to grow and flow for all to know...

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CHAPTER 1

INTRODUCTION

Educational stakeholders opportunistically search for technological solutions to closing persistent achievement gaps (Cheung, 2013; Cheung & Slavin, 2013; National Mathematics Advisory Panel, 2008; Steenbergen-Hu & Cooper, 2013; U.S. Department of Education, 2010; Woodward & Rieth, 1997; Xin & Jitendra, 1999). With instructional expectations growing exponentially (Alloway, 2011; D. Fuchs, Fuchs, & Compton, 2012; Maccini, Gagnon, & Hughes, 2002; No Child Left Behind, 2002; U.S. Department of Education, 2010), finding viable solutions is paramount. Cheung and Slavin (2013) assert, "the question is no longer whether teachers should use educational technology or not, but rather how best to incorporate various educational technology applications into classroom settings" (p. 102). However, in several studies using computer-based mediums for mathematics remediation, results do little to inform pedagogy for unidentified persistent poor performers (Browder, Spooner, Ahlgrim-Delzell, Harris, & Wakeman, 2008; Cheung & Slavin, 2013; Gersten, Chard et al., 2009b; Li & Ma, 2010; Rakes, Valentine, McGatha, & Ronau, 2010; Slavin, Lake, & Groff, 2009; Steenbergen-Hu & Cooper, 2013).

This dissertation seeks to clarify the relationship between engagement time and the use of Assessment and Learning in Knowledge Spaces (ALEKS), a web-based intelligent tutoring system, for its effect on performance for students' with persistent deficits in mathematics (PDM). Chapter 1 will present the background to the hurdles faced by those with PDM and provide context for the use of ALEKS as an educational technology. This chapter will also present a description of the purpose of the study, the problem statement, essential questions driving this study, its significance to the field, and definitions of key terms.

Background of the Problem

Time needed to learn exists as a function of a person's abilities, opportunities, instructional quality, and aptitude for a given subject (Carroll, 1963, 1989). The amount of time, however, does not necessarily offer a direct correlation with the parameters of engagement (Carroll, 1963, 1989; Crawford, Carpenter, Wilson, Schmeister, & McDonald, 2012; Miller & Mercer, 1997). For students with persistent deficits in mathematics (PDM), who consistently perform in the lowest quartile of academic performance; do not produce at the same rate as their typically achieving peers (Beal, Adams, & Cohen, 2009; Cirino, Fletcher, Ewing-Cobbs, Barnes, & Fuchs, 2007; L. S. Fuchs et al., 1997; Powell, Fuchs, & Fuchs, 2010; Vukovic, 2012; Vukovic & Siegel, 2010). In some cases, this appears as a three-to-five year gap in achievement (Geary, 1993; Geary, 2011b; Geary, Hoard, Byrd-Craven, & DeSoto, 2004; Judge & Watson, 2011; Mazzocco, 2005; Mazzocco & Kover, 2007; Piazza et al., 2010). Without effective remediation, students with PDM are more likely to suffer from academic disparity, emotional trauma, dysfunctional daily living skills, and economic hardship

(Acosta & Martin, 2013; Mastropieri, Scruggs, & Chung, 1998; Miller & Mercer, 1997; Rumberger & Palardy, 2005).

Computer-based mediums like intelligent tutoring systems (ITS) claim several pedagogical advantages perceived as beneficial to good teaching (Gagné, 1981; House, 2011; Seo & Bryant, 2010; Seok, DaCosta, Kinsell, Poggio, & Meyen, 2010; Torgesen, Wagner, Rashotte, Herron, & Lindamood, 2010). However, critics of technological mediums argue such mediums offer minimal, if any, benefit to instruction and that their popularity exceeds their capacity to improve academic outcomes (Clark, 1983, 1994; What Works Clearning House, 2013). Research suggests computer-based mediums do not offer a universal solution to closing the achievement gap (Campuzano, Dynarski, Agodini, & Rall, 2009; Cheung & Slavin, 2013; Dynarski et al., 2007; National Mathematics Advisory Panel, 2008; Slavin et al., 2009). They do, however, seem beneficial to several sub-populations and varying conditions within K-12 instruction (Craig et al., 2011; Craig et al., 2013; L. S. Fuchs et al., 2006; Geary, Bow-Thomas, & Yao, 1992; Leh & Jitendra, 2012; Mitchem, Koury, & Fitzgerald, 2008; Stillson & Nag, 2009). With this in mind, the following sections provide a background for the instructional terrain faced by secondary students' with PDM as educational stakeholders attempt to effect change with the aid of ITS.

Persistent Deficits in Mathematics

The complex maturation of mathematics presents an amalgamation of interrelated skills, which depend on each other for effective application (Curriculum Development and Supplemental Materials Commission, 2005;

Gersten, Chard et al., 2009b; National Mathematics Advisory Panel, 2008). Both correlating and independent cognitive strategies work together to develop mathematical competencies (L. S. Fuchs et al., 2005; Geary, 2007, 2011a, 2011b; Ginsburg, 1997; Swanson & Jerman, 2006; Vukovic, 2012). With the numerous demands for skill development, students face an equal number of hurdles to traverse the instructional landscape of classroom learning. However, for students' with PDM, the limited understanding of variables influencing performance convolutes effective remediation (Fletcher, Lyon, Fuchs, & Barnes, 2007; L. S. Fuchs, 2009; Geary, 2011a, 2011b; Judge & Watson, 2011).

Identification. Criteria for defining PDM are formative at best (Geary, 2011b; Montague & van Garderen, 2003; Morgan, Farkas, & Qiong, 2009; National Mathematics Advisory Panel, 2008; Watson & Gable, 2013). Multitudes of variables contribute to mathematical discrepancies impeding construction of a formal definition (Watson & Gable, 2013). Several markers of ability, however, provide insight to discerning the subgroup of students' with PDM. For example, researchers use intelligence quotients or reading ability to establish cut scores for the characterization of students with PDM (Geary, 2011a; Murphy, Mazzocco, Hanich, & Early, 2007; Watson & Gable, 2013). Unfortunately, neither accurately account for the pervasive nature of PDM (Gallistel & Gelman, 2005; Geary, 2007, 2011b; Gersten, Chard, et al., 2009a, 2009b; Ginsburg, 1997). Prior research suggests performance at or below the 25th percentile over consecutive years (e.g., two or more) on standardized tests of mathematical achievement provides the most viable cutoff to begin the identification process (Gallistel & Gelman, 2005; Geary, 2007, 2011b; Gersten, Chard, et al., 2009a; Ginsburg, 1997). Correlation between these and other markers of ability improve the accuracy of identification (Geary, 2011b).

Etiology, characteristics, and outcomes. Within the context of instruction, the effects of PDM on student performance mimics those errors typically made by children while learning a new skill (Geary, 2011a; Gersten, D. J. Chard, et al., 2009b; Maccini, McNaughton, & Ruhl, 1999; Mazzocco, 2005; Murphy et al., 2007; Watson & Gable, 2013). However, the severity of PDM is not measured by the number of errors made but rather by the variety of errors made (Geary, 2011b). Research suggests a multitier, compounding condition where neurological, genetic, and environmental contributors mediate cognitive functions (Kovas, Haworth, Petrill, & Plomin, 2007; Mazzocco & Thompson, 2005; Miller & Mercer, 1997; Murphy et al., 2007; Watson & Gable, 2013). These etiological components interrupt the expected processes of working memory, inhibition, and other subordinate functions used in learning new information (Murphy et al., 2007; Swanson & Jerman, 2006; Watson & Gable, 2013). The resulting outcome on student performance presents persistent deficits in processing and retention, which exceed the contributions of intelligence and/or environment (Andersson, 2008; Kovas et al., 2007; Meyer, Salimpoor, Wu, Geary, & Menon, 2010; Montague & van Garderen, 2008; Woodward, 2004).

In context. Students' with PDM typically use immature mathematic skills to solve problems (Andersson, 2008; L. S. Fuchs, Fuchs, & Compton, 2012; Garnett, 1998; Geary, 1993; Geary, 2007, 2011a, 2011b; Gersten, Chard, et al., 2009a, 2009b; Gersten, Jordan, & Flojo, 2005; Kovas et al., 2007; Mazzocco, 2005; Meyer et al., 2010; Montague & van Garderen, 2008; Swanson & Jerman, 2006; Watson & Gable, 2013; Wilson & Swanson, 2001; Woodward, 2004). When adding the addends in a problem (e.g., 3 + 5 = 1,2,3, +4,5,6,7,8), students with PDM commit more errors of magnitude and order (e.g., 1,2,3, + 5,6,8,10). Relative to procedural deficits, their fact fluency deficits offer a greater hurdle to development of mathematical competency (Chong & Siegel, 2008). Students' with PDM tend to retrieve incorrect information and put an extensive amount of pressure on their cognitive processes to retrieve any information, thus increasing the complexity of problem solving (Geary, 2005). This persistency in procedural and fact fluency deficits contributes to the three-to-five-year gap in achievement seen in students with PDM (Chong & Siegel, 2008; Cirino et al., 2007; L. S. Fuchs, Fuchs, Hamlett, et al., 2008; Geary, 2004, 2011b; Mandl & Lesgold, 1988). Learning hurdles, such as these place temporal demands on instructional capacity exceeding the finite amount of engagement time available. ITS offer one solution, gaining interest among educational stakeholders, with their ability to diversify instruction on an individual level.

Educational Technology and Intelligent Tutoring Systems

The quest for technological solutions to enhance the optimization of learning spans more than half a century (Carroll, 1989; L. Gray, Thomas, & Lewis, 2010; Marino & Beecher, 2010; Nicholson, 2007; Woodward & Rieth, 1997). Computer-assisted instruction in the 1960s, 1970s, and 1980s provided alternatives to traditional pen and paper activities like drill and practice of basic math facts (*Mandl & Lesgold*, 1988). Clark (1983) argued that features like these better address the cost of instruction and poorly mediate students' instructional needs. Hardware, software, and the theories used to design technological mediums provided strict parameters for application, limiting its viability to diagnosing instructional need or delivering associable feedback (Clark, 1983, 1994; *Mandl, & Lesgold*, 1988; Woodward, 2004). In general, early iterations offered limited applicability to the most needy.

Pedagogical relevance. Nevertheless, educational stakeholders continue to seek new ways to meet the needs of every child through the use of technology (*Mandl, & Lesgold*, 1988). For example, ITS, an advanced form of computer-assisted instruction (CAI), provide instructional components beneficial and more applicable to individual needs (Aleven, McLaren, Sewall, & Koedinger, 2006; Allsopp, Alvarez McHatton, & Farmer, 2010; Anderson & Gluck, 2001; Chien, Yunus, Suraya, Ali, & Bakar, 2008; Conati, Aleven, & Mitrovic, 2013; Gersten et al., 2007; Koedinger & Corbett, 2006; Kulik, 2003; Pane, Griffin, McCaffrey, & Karam, 2013; Seo, 2008; Seo & Bryant, 2009; Tienken & Maher, 2008) and a significant departure from prior offerings of didactic and obtuse pedagogical designs (*Mandl, & Lesgold*, 1988) by integrating artificial intelligence, mitigated instruction, multi-media interface, and web-based access to increase the utility and extend the opportunities to learn (Aleven, McLaren, Sewall, et al., 2006; Allsopp et al., 2010; Anderson & Gluck, 2001; Chien et al., 2008; Conati et al., 2013; Gersten et al., 2007; Koedinger & Corbett, 2006; Kulik, 2003; J. F. Pane et al., 2013; Seo, 2008; Seo & Bryant, 2009; Tienken & Maher, 2008). In this vein, ITS uses multiple cognitive theories along with multistep cognitive and metacognitive strategies to evaluate, adapt, differentiate, and facilitate instruction (Allsopp et al., 2010). In addition, advancements in graphics, audio, and video enable a content-specific interface, aiming to improve the instructional focus within the medium (Gagné, 1981; Gagné & Merrill, 1990; Gagné, Wager, Golas, Keller, & Russell, 2005; Min & VanLehn, 2010). Further, the system's interface appears pedagogically appropriate for instruction, with (a) explicit and targeted instruction, (b) a firm conceptual foundation, (c) deliberate and immediate drill and practice, and (d) formative and data-driven feedback to advance student learning (Aleven, 2013; Aleven, McLaren, Sewall, et al., 2006; Allsopp, Alvarez McHatton, & Cranston-Gingras, 2009; Allsopp et al., 2010; Pane et al., 2013). With these instructional features in mind, the use of ITS appears at the leading edge of instructional evolution.

ALEKS. ALEKS exemplifies the advancements seen in educational technology today. ALEKS uses a web-based interface to provide instruction anytime and anywhere (Canfield, 2001). This ITS uses expert content models, knowledge space theory, artificial intelligence, and a number of instructional interface components to assess, infer, and evaluate student ability within a given content (Carroll, 1989). ALEKS uses mastery learning and an open-ended response model, which uses mathematical notation, to evaluate students' content knowledge (Canfield, 2001). With this information, ALEKS offers students several developmental pathways to achieve content mastery. Along each pathway, students take formative assessments to reevaluate their content mastery (Canfield, 2001). Based on these results, ALEKS provides formative feedback on a student's content retention and mastery. Further, ALEKS adapts instructional pathways to fit these present estimates of ability and provides spiral reviews tailored to individual needs (Canfield, 2001).

Instructional application. The capacity to facilitate stand-alone academic courses, extend classroom instruction, and provide individualized remediation exemplify the application and optimization potential of ALEKS (Aleven, 2013; Aleven, McLaren, Sewall, et al., 2006; Canfield, 2001; Graesser, Conley, & Olney, 2012; Steenbergen-Hu & Cooper, 2013). Instructional providers can manipulate daily lessons to align with whole class, small group, or individual academic needs (Canfield, 2001; Craig et al., 2013; Li & Ma, 2010; Tienken & Maher, 2008; Xin, 1999). ALEKS includes several syllabi that support instructional modification and offers alignment with several McGraw-Hill textbooks (Canfield, 2001). In addition, ALEKS also provides several data streams to inform and design focused instruction (Canfield, 2001). Measurement of engagement time, skills practiced, skills mastered, and skills mastered per/hour provide significant markers for such modifications to instruction (Canfield, 2001).

Potential vs. production. Current research on the use of technological solutions for mathematical remediation predominately focuses on early intervention in elementary instruction (Cheung & Slavin, 2013; Li & Ma, 2010; Rakes et al., 2010). Among the literature reviewed in this study, research aimed to address issues associated with basic computation, fact fluency, procedural fluency, and word problems. However, a significant gap in the literature exists for students' showing PDM at the secondary level of formal education (National Mathematics Advisory Panel, 2008; Slavin et al., 2009). Remediation in algebra, for example, offered little to suggest ITS or any computer-based medium significantly improve instructional outcomes. Li and Ma (2010) contend the narrow scope of study, focused on achievement, in the primary years impedes the ability to determine what factors influence outcomes across the K-12 spectrum.

In terms of instructional components, ALEKS presents a formidable argument for its use as an instructional medium. However, potential alone does not justify use (Clark, 1994). Guidelines for instruction charge educational stakeholders with the responsibility of ensuring that instructional mediums provide measures of accountability to justify use (Allsopp et al., 2009; Chien et al., 2008; National Mathematics Advisory Panel, 2008; No Child Left Behind, 2002; U.S. Department of Education, 2010). Most of the studies conducted on the use of ALEKS, however, focused on post-secondary education (What is ALEKS?, n.d.). Very little research exists or justifies ALEKS's use in the K-12 environment. Several accountings on effect reflect homogeneous ability levels, produced no significant gains, and used traditional normative measures of achievement to determine efficacy (Calhoun, 2011; Craig et al., 2011; Craig et al., 2013; Grenier, 2013). While these studies focused on students in need of remediation, a significant literature gap exists on the influence of variables like engagement time for groups of varying ability.

Problem Statement

The growing expectations for mathematical competency seek to raise the learning curve and maximize instructional capacity (Bozick & Ingels, 2008). In application, this instructional climate rewards those with the ability to keep pace with the breadth and depth of instruction (Miller and Mercer, 1997). For those with PDM, the present pace of instruction may present its own learning challenge (Allsopp et al., 2010; Carroll, 1963; Cheung and Slavin, 2013; Chong and Siegel, 2008; Fuchs, 2009; Fuchs & Fuchs, 2007; Fuchs, Hamlett et al., 2008; Miller and Mercer, 1997; Murphy et al., 2007; Watson & Gable, 2013). An individual's ability to understand instruction and desire to persevere and learn a new skill may depend on the amount of time available to learn (Carroll, 1963). However, increasing requirements for achievement do not come with equitable amounts of instructional time. This raises the value of efficient intervention to improve student achievement.

Unfortunately for those in the secondary setting, the limited research to close the achievement gap in math offers little value to their instructional context (Cheung and Slavin, 2013; Fuchs & Fuchs, 2007; Geary, 2011b; Gersten, Beckmann, et al., 2009; Gersten, Chard, et al., 2009b; Watson and Gable, 2013; Zheng, Flynn, & Swanson, 2013). More specifically, most of the available research on PDM exists for the early primary years of development. For high school students this lack of research limits the understanding of PDM and how best to address this deficit (Watson & Gable, 2013). In addition, many of the present findings lack generalizable conditions for comparison or reproduction on larger scales (Alper & Raharinirina, 2006; Azevedo & Bernard, 1995; Scruggs et al., 1987; Xin & Jitendra, 1999; Zheng et al., 2013). Thus, the problem addressed in this study is the lack of generalizable data on the use of interventions to improve student achievement, using engagement time for students with PDM.

Purpose Statement

Technology's potential to support individual instructional needs appears promising (Allsopp et al., 2010; Cheung and Slavin, 2013; Dynarski et al., 2007; L. S. Fuchs et al., 2006; S. Gray et al., 2012; Li and Ma, 2010; National Mathematics Advisory Panel, 2008; Seo & Bryant, 2009; Seo & Bryant, 2010). With the vast array of platforms and mediums offered as technological solutions, this comes as little surprise in the 21st century (Cheung & Slavin, 2013). For example, enhanced versions of computer-assisted instruction offer media-based, differentiated engagement, and deliberate instruction of specific skills (Allsopp et al., 2010). Unfortunately, very few studies of technological interventions include those with PDM (Cheung & Slavin, 2013; L. S. Fuchs et al., 2006; Gersten, Chard, et al., 2009; National Mathematics Advisory Panel, 2008). In many of these studies, the effect size, sample size, and length of study, were small and thus raised questions of validity. Furthermore, Cheung and Slavin (2013) stated that these discrepancies in validity and reliability highlight design error, results tampering, or design bias. Inferably, the gap in research for the use of Intelligent tutoring systems for those with PDM highlights a significant need for continued study.

The purpose of this cross-sectional study is to test the capacity of Carroll's (1963) model of school learning regarding the use of ALEKS as a form of intervention to improve student achievement. Ninth-grade high school students' with PDM from the Fisher Creek Unified School District provided the sample population for the analysis of these variables. To these ends, this study controlled for (a) gender, (b) socioeconomic level, (c) prior reading achievement, (d) prior math achievement, and (e) attendance. In this analysis, engagement time is measured in minutes of engagement for the length of treatment with ALEKS. In addition, achievement refers to student performance on the district created Algebra I assessment.

Research Question

This study will explore the following research question: What effect does computer-assisted instruction (CAI) have on the achievement of students with persistent deficits in mathematics (PDM)?

Significance of the Study

Gersten, Chard, et al. (2009b) performed a meta-analysis on mathematical strategies used with learning disabled students over the previous 30 years. While they found several strategies to be effective, they noted several discrepancies with regard to low-performing students. Gersten and his colleagues noted a lack of viable and reliable data to support significant effect sizes seen in many of the studies analyzed, especially with those students who would qualify as having PDM. Likewise, the National Mathematics Advisory Panel (2008) reiterated the need for continued research to find effective interventions for those with PDM. Their support goes so far as to say "there is a critical need for stimulating and supporting through federal funding of additional high-quality research to address this major national challenge" (National Mathematics Advisory Panel, 2008, p. 49).

Scope of the Study

The study seeks to evaluate the use of ALEKS as a supplemental medium. Further, the target population is ninth-grade students exhibiting PDM. Students taking an algebra readiness supplemental course, engage with ALEKS for three hours a week for six months during the academic year. The following section provides the assumptions, limitations, and delimitations associated with this study.

Assumptions of the Study

This quantitative cross-sectional analysis employs a number of assumptions about the ITS ALEKS, the sample, population, and the context of instruction. The developers of ALEKs claim it measures of engagement time as a product of user interface and not a calculation of how long a student appears logged-in. Therefore, this study assumes ALEKS's measures are accurate depictions of engagement. The developers of ALEKS also claim that the instructional modeling ITS supports students within their individualized zones of proximal development and adapts as needed. This study assumes the instructional medium presents lessons, models, and support materials within this zone and is reflective of their prior performance.

While ALEKS does offer web accessibility, extending the opportunities to learn outside of the classroom setting, this study assumes that students do not have access to the internet outside of the school setting. Further, the ALEKS coordinator facilitates ongoing training on the use of the ITS for educational providers within the district. This study assumes this training adequately instructs providers on how to use ALEKS to support their students. Finally, ALEKS offers student a tutorial on its use. This study assumes the instruction provided adequately informed students on the use of interface tools to use ALEKS effectively.

Sample population. Assumptions about sample population focus on their interface with ALEKS and the Algebra I assessments. With both the initial and post Algebra I assessments, this study assumes these tests adequately assessed algebra content knowledge. Further, this study assumes students answer earnestly and honestly to these assessments, to the best of their ability at the time of testing. This study assumes that students optimized their opportunities to learn with ALEKS by limiting distractions and answering questions to the best of their abilities. With this in mind, this study assumes students did not attempt to manipulate ALAKS by continuously guessing or using peers or a calculator to answer questions when not permitted.

Context of instruction. Several instructional variables influence students' ability to learn. This study assumes the instructional environment provided a supportive context for instruction. This study also assumes that educational providers afforded appropriate blocks of time for the use of ALEKS.

In addition, this study assumes that educational providers took responsibility to ensure that students independently engaged with ALEKS on their own work. Finally, this study assumes that educational providers managed instruction on ALEKS to support their individualized instruction.

Study Delimitations

The study focuses on the effects of engagement time on student performance. To these ends, this study avoided the following measures:

- Comparisons of interventions offer significant benefits to pedagogical choices; however, they do not support an improved understanding of how engagement time with a specific intervention influences student outcomes. Therefore, this study avoids comparisons of interventions.
- Experimental studies that measure effect size inform educational stakeholders on the broad application of its use; however, students' with PDM represent a small sample of the student population. Their weighted effect lacks the magnitude to significantly influence cumulative findings. Therefore, this study avoids cumulative statistical analysis of student performance or randomized samples that inaccurately represent the influence of engagement time for subpopulations with varying ability levels.
- A number of studies evaluate the qualitative relationships between students and computer-based medium (e.g., motivation, boredom, anxiety, etc.,). While these studies offer significant information on

students' interaction with the interface, they do not inform instruction on the temporal demands an interface may require to effect change. Further, they offer no significant measures with the use of interventions already adopted by school districts. Therefore, this study avoids qualitative measures of engagement with ALEKS.

- This study avoided students in special education. The identification of learning disability influencing mathematic performance greatly improves the instructional measures taken to improve learning conditions; however, this study focuses on currently unidentified students' with deficits in math, exhibiting persistent poor performance, and without the benefits of instructional modifications or accommodations.

Study Limitations

A number of limitations influenced the scope of study in this research. Out of the more than 800 students using ALEKS for remediation, this study sought a sample size of 400 or more students. However, a significant lack of statistical data limited the sample to 138 students. In addition, ALEKS provides individualized learning pathways with multiple starting points. Therefore, comparisons of specific skill sets for performance gains require instructional manipulations by the educational providers. Since this study used archival data, the context did not support such an evaluation. Further, while the focus of this study independently evaluated the effects of engagement time with ALEKS, a lack of a control or comparison group limits the value of results in comparison to other research or other instructional environments.

The limitations of completing this dissertation also influenced the scope of study. Due to the temporal demands of this study, no comparisons with standardized measures of achievement were included in this study. ALEKS provides measures of retention for every student; however, this measure requires each educational provider to run an independent report for every student. This informative statistic could not be acquired in a timely manner for inclusion in this study.

Definitions of Key Terms

Achievement gaps occur when one student subgroup outperforms another subgroup and the difference in the achievement mean is statistically significant, that is, larger than the margin of error (Lipsey et al., 2012).

California Standards Test (CST) measures students' progress toward achieving California's state-adopted academic content standards in English language arts (ELA), mathematics, science, and history–social science and sets the goals that students should meet in each grade and subject tested (California Department of Education Assessment Development and Administration Division, 2013).

Computer-assisted instruction (CAI) is defined as the use of a computer to provide instructional contents (Seo & Bryant, 2009, p. 914).

Explicit instruction "means that teachers provide clear models for solving a problem type using an array of examples, that students receive extensive practice in use of newly learned strategies and skills, that students are provided with opportunities to think aloud (i.e., talk through the decisions they make and the steps they take), and that students are provided with extensive feedback" (National Mathematics Advisory Panel, 2008, p. xxiii).

Explicit systematic instruction "typically entails teachers explaining and demonstrating specific strategies and allowing students many opportunities to ask and answer questions and to think aloud about the decisions they make while solving problems" (National Mathematics Advisory Panel, 2008, p. 48).

Formal mathematics is a written, codified body of material conventionally defined and agreed upon (Ginsburg, 1997, p. 23)

Intelligent tutoring systems (ITS) are computer-based instructional platforms, which use knowledge theories, artificial intelligence, along with other advancements in technology to provide individualized targeted instruction within a given curriculum (Chien, Yunus, Suraya, Ali, & Baker, 2008)

Learning disability (LD) refers to an individual having been assessed and diagnosed with one of 14 categorical disabilities. These include autism, deafness, visual impairment, specific learning disability, etc. (Geary et al., 2004)

Low-achieving (LA) peers are students at the 11th to 25th percentile on standardized performance measures of the mathematical achievement for two or more consecutive years (Gersten, Chard, et al., 2009a; Mazzocco & Myers, 2003; Murphy et al., 2007; Swanson & Jerman, 2006).

Mathematical interventions are instructional practices and activities designed to enhance the mathematics achievement of students with LD. (Gersten, Chard, et al., 2009b, p. 1205)

Procedural skill is the ability to use algorithms to solve simple and complex calculations (Chong & Siegel, 2008).

Retrieval skill is the ability to fluently retrieve basic math facts from memory (Chong & Siegel, 2008).

Typically achieving (TA) peers are students performing at or above the 39th percentile on standardized performance measures of the mathematical achievement for two or more consecutive years (Geary & Hoard, 2005; Geary, 2004, Geary, 2010; Geary, 2011b; Gersten, Beckmann, et al., 2009; Mazzocco, 2007; Mazzocco & Myers, 2003; Murphy et al., 2007).

Working memory (WM) "represents the ability to hold an idea or piece of information in mind while simultaneously engaging in other mental processes" (Geary et al., 2011a, p. 207).

Organization of the Dissertation

Chapter 1 presented the background and difficulties faced by students with PDM, including the effects of PDM on academic proficiency, cognitive processing, and daily living. This chapter provided insight into the effects of the underlying deficits on acquisition of mathematical competencies and continued with a discussion ITS as an alternative instructional intervention.

Chapter 2 will present pertinent findings describing the nature of PDM and the relevancy of ITS as a supplemental medium for instruction. Chapter 3 will provide details of the proposed study design, population, setting, data collection, and analysis used in this study.

CHAPTER 2

REVIEW OF THE LITERATURE

As an instructional medium, ITS appear at the leading edge of development for forward thinking solutions for closing the achievement gap (Inan, Lowther, Ross, & Strahl, 2010). However, measures of efficacy with an intervention reflect the relationship between the user and the medium. With this in mind, the resulting gains in achievement exist as the product of influential variables facilitating instruction. Conduits of instruction, like opportunities to learn, rarely afford significant manipulation supportive of the time students need to learn. When opportunities to learn fail to support students' needs, they also fail to support the resulting outcomes (Carroll, 1963). Therefore, outcome measures of achievement more effectively represent the congruency of capacity between the medium, the user, and the instructional variables influencing learning. In consideration of this paradigm, measures of efficacy with computer-based mediums require a significant understanding of the relationship variables of instruction impose on the medium and the user.

For students with PDM, interpretation of prior research on the use of ITS in a secondary setting appear inconclusive. While research does identify pedagogical methods to closing the achievement gap for these students (L. S. Fuchs, Fuchs, Powell, et al., 2008), the limited understanding of PDM imposes on students' ability to learn, along with the lack of literature on the use of ITS, presents a significant gap in the literature on the parameters of instruction conducive to their learning needs. Therefore, this study seeks to address these limitations by exploring the relationship between engagement time and student performance when using the ITS ALEKS. This chapter begins with the theoretical foundation of this study, which is followed by a review of empirical research related to the dissertation topic. This chapter concludes with a summary.

Theoretical Foundation

This dissertation proposal uses the theories undergirding Carroll's (1963) model of school learning (p. 728). According to Carroll (1963), competence in a given task equates to "the amount of time the learner actually spends on the learning task, [proportionate] to the total amount he needs" (p. 728). This model views the following as instructional variables influencing achievement: (a) aptitude, (b) perseverance, (c) opportunities to learn, (d) ability to understand instruction, and (e) the quality of instruction. According to Carroll, measures of performance indicate a students' ability to absorb the content within the given opportunities to learn. Theoretically, this paradigm views academic performance as a product of time needed to learn. The degree to which students with PDM achieve competency, the amount of time needed to learn, and how others view their achievement provides the theoretical foundation for the subsequent literature review.

Review of the Scholarly Empirical Literature

The use of ITS as a form of intervention offers several benefits that appear to align well with the needs of those with PDM (Allsopp et al., 2010; Burns, Kanive, & DeGrande, 2012; Cheung & Slavin, 2013; L. S. Fuchs et al., 2006; Gersten, Chard, et al., 2009b; Gray et al., 2012; Kroesbergen & Van Luit, 2003; Kulik, 2003; Kulik & Kulik, 1991; Li & Ma, 2010). The ability to provide targeted instructional content while extending the opportunities to learn may offer educators an equitable solution to the limited engagement time available for students with PDM in the secondary setting. Current research, however, does not conclusively support its use as a formidable instructional alternative for those with PDM (Gersten, Chard et al., 2009b; National Mathematics Advisory Panel, 2008). The following sections provide a foundation for understanding PDM, with an emphasis on ITS integration as an intervention for supporting mathematical competencies.

Conceptual Framework

The conceptual framework for this study is grounded in three concepts. First, standardized measures of achievement mislead efforts to evaluate the potential of an instructional medium for students with PDM. Second, the lack of understanding of variables influencing algebra competency development further distorts the development and assessment of instructional mediums. Third, engagement time is a fundamental variable that facilitates the time needed to learn. The fidelity of its use explicitly correlates with the outcomes of performance; however, parameters for varying ability levels lack the empirical analysis and subsequent specificity for implementation to effectively inform instruction.

Characterizing Performance

Students' with PDM mimic their LA and LD peers on mathematical acuity and cognitive and metacognitive reasoning (Andersson, 2007, 2008; Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Brown, 2013; Bryant et al., 2008; L. S. Fuchs et al., 2005; L. S. Fuchs, Fuchs, & Compton, 2010). Research suggests that even when students' with PDM match their TA peers in rate of growth, the initial gaps in achievement persist (Chong & Siegel, 2008; Murphy et al., 2007). However, at this time remediation efforts lack the empirical understanding of mathematical difficulties to improve instruction (Cheung & Slavin, 2013; Codding, Burns, & Lukito, 2011; Kroesbergen & Van Luit, 2003; Min & VanLehn, 2010; Slavin et al., 2009; Steenbergen-Hu & Cooper, 2013). To better understand the parameters faced, by students' with PDM, the following sections attempt to characterize parameters of performance relative to their LA and LD pears.

Perceptions of performance. Perceptions on the use of computer-based mediums at the secondary level appear relatively moderate with no significant (Cheung & Slavin, 2013; Gersten, Chard et al., 2009b; Li & Ma, 2010; Min & VanLehn, 2010; Steenbergen-Hu & Cooper, 2013). Cheung and Slavin (2013) interpreted, the difference in instructional gain between secondary students (effect size = 0.14, $p < .001$) and elementary students (effect size = .17, $p < .001$) as nominal; and suggest students at the secondary level may not need such specificity in approach (i.e., didactic drill and practice) to obtain content competency. Steenbergen-Hu and Cooper (2013) reconstituted studies samples on the use of ITS with students having special needs to support a two-tier evaluation of effect between elementary and secondary students. Their results revealed no significant difference in using ITS as an instructional alternative ($Q_b = 0.12$, $p = .726$). Li and Ma (2010) echoed these results, suggesting again a nominal difference between instructional environments (unstandardized $\beta = -0.22$, $p < .05$).

In general, research suggests ITS offers little to no significant threat to the learning of mathematics for secondary students, seen on comparable outcome measures. In contrast, Steenbergen-Hu and Cooper (2013) also found for low-achieving (LA) students, ITS negatively influenced achievement, relative to their TA peers ($Q_b = 9.24$, $p = .002$). This would suggest conflicting results between subpopulations based on perceived ability.

Outcome measures. In determining the relative treatment effects of an intervention, Gersten, Chard, et al. (2009a) synthesized 44 studies with K-12 students to discern performance effect, organization of activity, and enhancements of instruction. Their results suggest normative standardized posttest measures negatively affected the determination of treatment effect size when compared to researcher-developed assessments ($SD = -0\ .35$, $\beta = -0.23$, $p < .05$). In comparison, Steenbergen-Hu and Cooper (2013) analyzed studies on ITS under similar conditions and found course-related measures of performance generate larger effect sizes ($g = 0.19$, 95% CI [.11, .27]), than standardized measure of achievement ($g = 0.02$, 95% CI [-.02, .06]). Li and Ma (2010) also found similar results in their synthesis of research on the use of computer-based mediums. Taken together, these results imply standardized measures of achievement produce smaller treatment effect when compared to curriculum-based measures, regardless of instructional medium.

Ding and Davison (2005) adds value to Gersten, Chard, et al.'s (2009a) interpretation of expected performance on standardized measures, relative to students with PDM in their cross-sectional longitudinal analysis of growth patterns for LA students. Their three-year study of 719 students' mathematical performance, including 379 fifth graders, analyzed annual standardized norm referenced tests of achievement to distinguish patterns of performance among subpopulations (Ding & Davison, 2005). Part of their analysis used multiple *t*-tests to establish subgroup profiles for students considered limited English proficient, TA students, and students in special education.

To compare subpopulation performances, Ding and Davison (2005) established a profile index for the standardized measure of achievement. The fifth grade cohort (N = 366) provided an average growth rate of 15.41 and standard deviation of 8.45 units, annually. Initial performance profiles indicated that students in special education (N = 13) and their limited English peers (N = 34) presented a lower baseline of achievement (Special Education = 618.85 vs. rest of sample = 645.39; limited English peers = 627.97 vs. rest of sample = 646.11). However, regardless of designation, Ding and Davison (2005) found no significant difference in growth rate between groups. With further analysis, they found growth rate as a more profound variable of influence on closing the achievement gap. There results suggest comparisons of performance across subpopulations using standardized measures offer little value to determining the reduction in achievement gap. Further, Ding and Davison's (2005) results suggest that, with evaluations of supplemental interventions for specific subpopulations, comparatively relative change in growth rate exists as a more significant variable of value.

In another study, Craig et al. (2011) analyzed LA students using the state-adopted standardized measures to compare performance gains from afterschool programs. One group used ALEKS and the other received teacher-directed instruction. ALEKS is an ITS that provides independent instruction for each student to work at their own ability level with material they are ready to learn. This study used a randomized assignment to assess 291 sixth graders on the Tennessee Comprehensive Assessment Program measures of academic achievement to compare learning gains between students using ALEKS (treatment condition) to those in a teacher-mediated cohort (control group). Students participated for two hours a week for 25 weeks in either condition. Their results revealed that students in the ALEKS cohort who full participated in the after school program for more than 70% of time (n = 24) saw a significant performance gain relative to the teacher-directed cohort (t [22] = 1.41, p = .08, d = .47). While the small sample does not add credence to justify universal application of ALAKS, it does suggest greater and more associable results with an ITS relative to students' with PDM. In light of the previously discussed literature, their results suggest that, as a supplemental alternative, ALEKS provides instruction with the capacity to improve performance on standardized measures and may show an even more significant effect on curriculum-based measures.

Curriculum in Context

Within the domains of mathematics, the scope of this study centers on the variables of instruction associated with learning algebra. Research addressing the capacity of ITS to improve students' performance in algebra, present a significantly different picture from the holistic interpretation of learning mathematics provided above. Steenbergen-Hu and Cooper (2013) found for learning algebra (with and adjusted effect size g = -0.05, and a 95% CI of [-.13, .02]) results suggested a minimally negative effect size in comparison to learning math in general (g = 0.11, 95% CI [.04, .19]). However, these results appear subjective. In their analysis, Steenbergen-Hu and Cooper (2013) specifically used Cognitive Tutor as the only ITS providing algebra instructions. While literature on the use of ITS with algebra is sparse, their results distort perceptions of the viability within the field. What Works Clearing House (2013) reports Cognitive Tutor as an integrated mathematics program. More specifically, it is a multifaceted instructional system that uses an ITS for 40% of the school week. The What Works Clearing House (2013) analyzed 27 of studies on the Cognitive Tutor and found three that met the criteria with no reservations and three that met with some reservations. Their analysis of the ITS, across Grades 9-12, revealed mixed effect.

Rakes et al. (2010) addressed the issue in a meta-analysis targeting algebra instruction. They analyzed 82 randomized experimental trials and quasiexperimental studies for structural clarity between procedural and conceptual development with (a) instructional strategies, (b) use of manipulatives, (c) curriculum without technology, (c) use of technology tools, (d) and technology-based curriculum (Rakes et al., 2010). More than 56% of studies used in this analysis covered Grades 9 through 12. In general, Rakes et al. (2010) found value added through development of conceptual understanding (ES = 0.099, $p < .05$) exceeds the gains derived from developing procedural competency (ES = 0.044, $p < .05$) across all mediums of instruction. Further, Their results suggest computer-based curricula (ES = 0.305, $p < .05$) provided the most significant value added relative to all other approaches synthesized in this study. However, several limitations to this analysis cloud valid interpretation of results relative to those with PDM.

Most notably, Rakes et al.'s (2010) sample included advanced mathematics and science studies using algebra concepts. Inclusion of advanced classes, where students presumably possess a more than adequate understanding of the subject, does not support the identification of effective strategies for remediation of students with varying ability levels (L. S. Fuchs, 2009; Miller & Mercer, 1997; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011). Further, such inclusion also distorts variables influencing skill development. Without accounting for the alignment of instructional fidelity (which Rakes et al., 2010, acknowledged as an external limitation of the study), aptitude for the subject matter, or the time needed to learn, discounting duration of treatment seems premature (Carroll, 1963, 1989). Finally, a significant amount of research exists on the use of computer-based curricula in elementary, advanced placement courses, and at the secondary levels of instruction. However, for students with PDM, their LA peers (e.g., 25th to 50 percentile) and those with identified LD, a significant gap of viable literature informing instruction exists (Geary, 2011b; Gersten, Baker, & Lloyd, 2000; National Mathematics Advisory Panel, 2008). Thus, findings of the efficacy with computer-based curricula appear weighted toward instructional contexts outside traditional settings of Algebra instruction and remediation (e.g., seventh, eighth, and ninth grades).

Engagement Time: An Issue of Fidelity

Fidelity of an instructional medium's implementation significantly correlates with its capacity to effect change (Crawford et al., 2012). In the scope of this study, constructs of engagement time exist as influential variables of instructional fidelity. With this in mind, this section seeks to discern what added value does engagement time offer students' with PDM, relative to similar subpopulations.

In Gersten, Chard, et al.'s (2009b) generalized findings regarding concentration of time, the authors identified a negative relationship between the number of sessions within an intervention and student performance (SD = -0.003; β = -0.19). In contrast, Steenbergen-Hu and Cooper's (2013) evaluation of ITS with students considered low achieving and having special needs, duration significantly correlated with effect size (Q_b = 16.28, p = .000). Considering their study focused on similar performing subpopulations, Steenbergen-Hu and Cooper's (2013) results appear informative to identifying necessary instructional parameters for time concentration. However, as previously discussed, their study only used Cognitive Tutor, which is an integrated curriculum and consists of students' participation for 40% of the school week for the entire academic year. With this in mind, Steenbergen-Hu and Cooper (2013) also found that studies lasting less than one academic year provided a greater effect (Q_b= 6.48, p = .011). This conflict of data exemplifies the lack of clarity in understanding optimal conditions of time concentration. In addition, Slavin et al. (2009) contend the lack of empirical research lasting the academic year impedes the identification of structural features capable of effecting change. Inevitably, measures of engagement time offer conflicting results and lack the clarity to conclusively derive parameters of performance.

Chapter Summary

Chapter 2 provided a review of conceptual considerations for the integration of an ITS into the instructional plan for students having PDM. Carroll's (1963) model of school learning provided a theoretical framework to evaluate ITS as a form of intervention with students having PDM. Characteristics, criteria, and domains of PDM provided a comprehensive picture of the instructional challenges faced in closing the achievement gap. Additionally, a framework for instruction provided best practices for meeting the needs of those with PDM. Finally, this chapter reviewed the literature on ITS use with students having PDM, to distinguish correlating instructional practices that appear beneficial.

Clark's (1983,1994) position that educational technology offers no substantiated benefit outside of already proven practices of effective instruction remains inspirational to the study and to the development of computerized instruction. Research in the field of computer-assisted instruction with those having PDM has attempted to bridge the achievement gap with the use of adopted models of instruction, integrating prevailing technology, and subsequently assessing for efficacy (Allsopp et al., 2010; Burns et al., 2012; Fuchs et al., 2006; Kulik, 2003; Kulik & Kulik, 1991; Li & Ma, 2010; Seo & Bryant, 2009, 2010; Seo & Woo, 2010). Cognitive and metacognitive strategies, where students are given explicit instructions and asked to complete engaged activities to derive the appropriate responses, exemplify the current trend in research to meet students' needs through the adoption of proven instructional methods (Allsopp et al., 2010; L. S. Fuchs et al., 2006; Leh & Jitendra, 2013; Seo & Bryant, 2009, 2012; Seo & Woo, 2010). In addition, a review of the literature reveals a trend toward determining variables that improve student achievement (Agostino et al., 2010; Aleven et al., 2006a, b; Allsopp et al., 2010; L. S. Fuchs et al., 2006; Leh & Jitendra, 2013; Seo & Bryant, 2009, 2012; Seo & Woo, 2010). Seo and Bryant (2010) suggest a focus for continued research to refine the development of ITS's sustainability. L. S. Fuchs et al. (2006) stated, for those with PDM, future research needs to focus on instructional design of ITS. Recognizing the learning process, even within an ITS, may require explicit differentiation to meet the needs of specific subgroups. The authors of the National Mathematics Advisory Panel (2008) noted the viability of ITS's malleability for those with diverse needs. However, they recommend continued research on how best to use and design ITS to meet the needs of those with PDM. In summation, there is a need for studies to assess the efficacy of ITS when used with students with PDM.

CHAPTER 3

RESEARCH METHODOLOGY

Students with PDM face significant hurdles in obtaining the needed content competency to successfully progress through the instructional requirements in secondary education. As the instructional expectations increase, learning barriers become more prevalent and limiting to academic success. For example, hurdles like instructional engagement time and perseverance play significant roles in students' ability to learn. Unfortunately, in many cases these temporal demands exceed the capacity of traditional instruction. Research suggests that without appropriate remediation these limitations will persist through adulthood and diminish the students' quality of life. Educational stakeholders strive to find instructional models capable of overcoming these hurdles and improving the academic competency of students. ITS is one instructional medium gaining traction as a viable alternative to address the remediation needs of these students.

ITS are advanced forms of CAI. Their Instructional components, such as the use of artificial intelligence (AI) engines, adopted educational theories, the ability to extend the opportunities to learn, differentiation, and the utilization of good teaching practices, imply a high level of instructional quality. However, research on the use of ITS does not conclusively support their use. Studies focused on the use of ITS, however, rarely focus on students with PDM and the instructional time they need to learn.

Thus, the purpose of this study is to evaluate the relationship between ITS and student achievement for students with PDM. The underlying question is what effect does engagement time, when using ITS, have on the achievement of students with PDM?

Chapter 3 provides the methods and design used in this study. The perspectives used reflect a nonexperimental, descriptive, cross-sectional approach to infer probable causes, correlations, and predictions. In addition, the research design offers further depictions of the setting and sample along with descriptions of the data collection, instrumentation, and data analysis. The chapter concludes with a discussion of the validity of the study and the role of the researcher.

Quantitative Method Research

Steeped in postpositivistic philosophical assumptions, quantitative research uses mathematical models to evaluate the human condition (Creswell, 2013; Duffy & Chenail, 2009; Paul & Marfo, 2001). Through finite perspectives, researchers attempt to empirically describe, predict, or explain connections between measurable social phenomena (Duffy & Chenail, 2009; Paul & Marfo, 2001). In education, quantitative research seeks to inform leadership and instruction regarding practices, policies, and principles that provide relative consistency across comparable conditions (Paul & Marfo, 2001). Often referred to as the scientific methods, or the true sciences, proponents of these methods of study understand that all research is subject to error (Creswell, 2013); therefore, researchers prioritize reproducible, intentional, and valid methods of discovery. This methodology uses experiments, surveys, and statistical descriptors in its attempts to bridge the gap between what is perceived as knowledge and what the data would suggest (Duffy & Chenail, 2009). In these ways, quantitative research offers valuable credibility to qualitative research—either as a prerequisite or a subsequent service of study.

Discerning variables that can serve as both reproducible and calculable inherently lend themselves to quantitative designs (Creswell, 2013). The clarity in interpretation of these scientifically grounded methods provides researchers the ability to inform policy makers and practitioners with data-driven information on a broader scale (Paul & Marfo, 2001; Smart, 2005). However, quantitative methods, in their attempts to provide probable cause, face several hurdles of trustworthiness (Bickman & Rog, 2009; Creswell, 2013; Duffy & Chenail, 2009; Paul & Marfo, 2001).

Lack of validity presents the most consistent deterrent to methodological justification with quantitative research. Fragile assumptions of causal relations (internal validity), inability to reproduce results under generalizable conditions (external validity), misrepresentation of outcomes or inappropriate interpretation of the concept (construct validity), and inadequate methods measurement and analysis (statistical conclusion validity) offer significant impediments to a studies ' fit, worth, and possible impact (Bickman & Rog, 2009). Further, each of these present varying degrees of influence on every methodological endeavor, thus adding an additional layer of complexity to the analysis of results (Bickman & Rog, 2009; Lund, 2005). For example, researchers must account for human error, which can distort analysis of a given study. No research is without bias, therefore, researchers also must announce the most likely contexts for such errors to occur (Paul & Marfo, 2001). These would include sample choice, methodology, and interpretation of data, all of which offer significant opportunities for manipulation and misinterpretation of phenomenon, theory, and hypothesis (Bickman & Rog, 2009; Creswell, 2013; Duffy & Chenail, 2009; Lund, 2005). Nevertheless, researchers seek to ensure these pillars of quantitative methodology meet expected levels of construction, relative to the study being done, which significantly defines a study's fit, value, and capacity to influence.

The comparison of variables, like time on task and student performance, however, offers numerical identifiers. These two constructs of time and skill presentation, when juxtaposed, offer some level of understanding of the plausible relationship between instructional engagement, time on task, and the ability to transfer learned capacity to alternative conditions (Bickman & Rog, 2009; Carroll, 1963; Creswell, 2013). Similarly, identifying the number of attempts to obtain a given skill informs practitioners and policy makers on the commitment required by a given sample to reach an acceptable level of mastery, thus informing stakeholders on the instructional requirements for implementation and providing contextual identifiers for an analysis of efficacy.

The identification of calculable correlates for study (i.e., engagement time and academic performance) offers reasonable assumptions of causation

(Creswell, 2013). Further, the finite range of possible outcomes (e.g., the positive or negative effects of an intervention on student performance as measured through engagement time) risks being undervalued or missed in a more comprehensive evaluation (Creswell, 2013). The information obtained from research like this adds context to future studies analyzing effects of similar recurring outcomes (Bickman & Rog, 2009; Duffy & Chenail, 2009; Smart, 2005). Thus, quantitative measures inform educational policy and helps practitioners decide how to move past the conjecture of subjective knowledge interpretations to the identification of variables most likely to effect change or the elimination of those having no impact on the outcome (Creswell, 2013).

Research Design

This study uses cross-sectional research design. This design falls under the quantitative methodology, using quantitative data to locate probable causation between naturally occurring phenomena (Bickman & Rog, 2009; Creswell, 2013; Duffy & Chenail, 2009; Johnson, 2001; Paul & Marfo, 2001). Within the district used in this study, students not receiving a passing grade (e.g., A, B, or C) for their eighth-grade math class were given a pretest to determine qualifications for intervention, were provided an intervention to support their fundamental skill base, and then were given a posttest to assess their growth. The posttest, however, was the same assessment used for the initial assessment one year prior. These conditions provided a unique opportunity to assess the relationship between time spent on the intervention and the outcome measures.

Using engagement time and skills mastered per hour as measures of the time needed to learn and perseverance, this study aimed to describe the effects of time spent on ITS and achievement for students with PDM. The sample population was taken from the lowest quartile of students across the district. Archival data from both the district and the ALEKS software was used to perform correlation and regression analyses. These types of analyses do not support the declaration of cause and effect (Bickman & Rog, 2009); however, they do inform the direction of future research and reduce confounding variables by providing zones of proximal phenomenological analysis (Johnson, 2001). This design typically presents a first step in the evaluation of scientific research by narrowing the possible variables associated with the observed outcomes (Creswell, 2013).

Using a cross-sectional research design, this study seeks to explore the possible relationship between time engagement and student performance. The design was chosen for its compatibility with the complex conditions in this study. For example, this study takes place in the Fisher Creek Unified School District (FCUSD) and aims to describe the relationship between time engagement and their supplemental software, ALEKS. To describe this relationship, a premium was placed on validity and reproducibility of design choice. To these ends, archival data was used.

Archival data offered three benefits to the design of this study. First, the data obtained was not manipulated by the research and occurred within the natural setting of instruction, thereby reducing researcher bias and subsequent discrepancies with external validity (Lund, 2005). Second, this study used regularly collected archival data, which offers FCUSD, and other districts mimicking this design, the option to repeat this study year-to-year for a more detailed description of the possible value added for the larger population the sample represents. Cross-sectional studies face substantial criticism for the snapshot depiction of phenomena (Lund, 2005), which does not adequately account for demographic changes or the acumen of the instructional population from year to year. By performing a cross-sectional data analysis in the manner suggested by this design, the same cohort of students provides a baseline of performance, compares relatable variables of time and achievement across and between subjects, and offers this data with no direct involvement in the instructional process. Third, the design used here offers significant financial value by maintaining its affordability for annual reproduction.

This study aimed to inform stakeholders on the relationship between time engagement with ALEKS for those performing in the lower quartile of achievement. Within FCUSD, more than 85% of this population use ALEKS as a supplemental intervention, thereby making the identification of a comparison or a control group inadequate to meet the requirements of valid research (Creswell, 2013). Further, students performing in the lower quartile do not have an alternative program. Thus, an experimental model would not be appropriate for a study with this scope and fiscal capacity.

For those with PDM, a lack of understanding of what variables improve and impede learning, at the secondary level, present significant barriers to improving intervention (Fuchs, 2009; Geary, 2011a). This includes the complexity of academic content, cognitive development, and other real-world contexts, which make variable identification for this subpopulation an arduous and expensive endeavor. In asking, "what effect does ALEKS have on the achievement of students with PDM," this research seeks to find evidence of probable causation, or no relation, to build upon for future research. Thus, because of the lack of a viable comparison group, limited sample variation, and a focus on valid and reliable results, this cross-sectional research design offers a good fit. This model adds to the understanding of PDM at the secondary level and informs stakeholders of probable outcomes from the use of ALEKS.

Cross-sectional research design allows researchers to perform statistical analysis of archival information while supporting an unconventional temporal context (Johnson, 2001). For the purpose of this study, the period consists of one academic year. Further, each of the three schools participating in this study provided a multitude of instructional models while using ALEKS. However, the options available for instruction offered no consistency, even within school sites. This diversity of instruction continued to make comparisons of efficacy nonviable. Further, ALEKS allows students to work within their own zones of proximal development, which results in students covering the same skills but at different paces and in different order. This adds significant complexity to finding a viable sample group. However, these conditions lend themselves to the cross-sectional design under the conditions that this study compares time-engagement and summative achievement, both of which represent homogenous variables for the whole sample. Students participated in a pretest/posttest design within the context of instruction. This organic context also helps avoid bias in construct validity by providing a sequence of events outside the intervention of the researcher. Thus, the cross-sectional design supports the time frame, variables available for analysis, and the instructional context that naturally exists within the FCUSD.

In summation, the cross-sectional design offers the best fit for the purpose, problem, and research question presented in this study. This model supports the natural constructs already existing within FCUSD and allows the replication of this study within and outside the district. The data collected from this study over multiple years within the district support a better understanding of the value added with the possible use of ALEKS with regard to engagement-time. Finally, the affordability of this study, with the use of archival data, makes studies like these viable first starts in identifying cause and effect by providing direction for future studies to address.

The following sections outline the details of this cross-sectional analysis. This next section provides the setting, sample, and instrumentation used in the study. An explanation of the data collection procedures, analysis, validity, and the role of the researcher are also included.

Research Methods

This is a cross-sectional analysis of archival data. The statistical analysis performed here aims to advise stakeholders on the level of commitment to the ALEKS intervention required to see desired changes in performance. More specifically, this research seeks to identify the added value ITS may bring to those with PDM, within the scope of time-related constructs. To meet this goal and answer the subsequent research question, this study controls for age, sex, grade, socioeconomic level, prior performance, achievement, and attendance.

Setting

This study takes place in the FCUSD, which is located in Los Angeles County, California. More than 150,000 people live within the boundaries of the district. Almost 70% over the age of 18 are without a high school diploma, and 20% over the age of 25 are without a college degree. The average household income is below $45,000, and more than 20% of the population lives below the poverty line.

FCUSD is a high school district, servicing ninth- through 12th-grade students. Three elementary school districts feed into FCUSD's five high schools. These schools serviced more than 6,500 students during the 2013-14 academic year. Close to 85% of these students were eligible for a free or reduced-price lunch program, representative of the low socioeconomic level of the larger community.

Demographically, the district population reflects the greater community. Almost 75% of the population is Hispanic. Another 15% of the population is African American. Asian Americans and Caucasian Americans represent another 3% each. Approximately 25% of the students are English learners. Notably, during the prior school year, less than one third of the graduating class possessed the necessary academic proficiency to attend a California State University.

Sample

For the purposes of this study, samples from the 2013-14 ninth grade class were taken from three of the five high schools within FCUSD. FCUSD provides secondary education to several students from multiple elementary districts. These districts each have their own social, economic, and environmental cultures and climates. The heterogeneity in educational development and assessment offered by each of these subcultures complicates the evaluation process of instructional capacity and reproducible performance. To better understand the mathematical ability of the incoming ninth grade class, FCUSD administers an algebra placement exam prior to instructional assignment. This assessment is taken at the end of the eighth-grade academic year and prior to placement within the subsequent secondary instructional matrix for ninth grade.

Performance on the placement exam significantly influences the mathematical instruction an incoming student receives within FCUSD. All students are initially placed in Algebra I; however, those performing at or below the 60th percentile also receive additional support from an intervention class. This second group of students' receives curriculum support for Algebra I. Within this course, students use ALEKS for fundamental skill development, yet, this placement is tentative.

FCUSD tempers its own evaluation with the normalized measures provided by the CST results. After CST scores are available, students enrolled in the intervention course using ALEKS are given the opportunity to take an Algebra

I course only. More specifically, students performing at a basic, proficient, or advanced level on the CST in mathematics, regardless of the algebra placement exam scores, are allowed to eliminate this supplemental course. Thus, CST's normative comparisons, supersedes the district-derived analysis for determining placement. This allows students to move from the instructional context of Algebra I with supplemental ALEKS instruction to Algebra I only or a geometry course. Consequently, performance on the CST can only advance the instructional expectations and course adoption for each student.

Criteria for participation. This analysis focuses on the ability to learn, time needed to learn, and the perseverance needed to learn for those performing in the lowest quartile of academic proficiency. The sample population for this study was taken from three of the five high schools within the district and used only the ninth-grade class of 2013-14. Again, the research seeks to discern probable relationships between instructional engagement time and achievement for those using ALEKS for supplemental instruction. To these ends, this study used both district and ALEKS archives to retrieve quantifiable data for analysis. The following criterions were used to identify and analyze students' academic achievement and growth from pretest to posttest:

- A student must have been enrolled in the FCUSD as a ninth-grade student for the 2013-14 school year.
- A student must have taken the CST in seventh and eighth grade and have a qualifying scale score below 300.

- A student must have taken the Algebra I initial assessment at the end of eighth grade and have been placed in instructional support class for algebra to receive additional intervention.
- A student must have taken the initial assessment for ALEKS in ninth grade.
- A student must have used ALEKS between October 2013 and February 2014.
- A student must have a cumulative score for their academic proficiency within ALEKS reflecting their proficiency in the curriculum prior to March 1, 2014.
- A student must have taken the posttest in March of 2014.

In context, students' seventh- and eighth-grade CST scores were disaggregated to identify a population showing persistent low performance year to year (having scale scores below 300). After first Identifying this group of students, the sample population was taken from the ninth grade class who were enrolled in a mathematics intervention course that used ALEKS as a part of their instructional process for the 2013-14 school year.

Demographics. A sample of 138 students met the above criteria for participation in this study. This sample includes participants from each of the three schools: 38 from site A, 59 from Site B, and 40 from site C. Those identified as Hispanic composed more than 71% of the given sample. African Americans provided an additional 22.5%. Those of Caucasian, Asian, and the Pacific Islander heritage provided the remaining 7% of the sample population.

More than 93% qualified for the free or reduced-price lunch program. Male students composed 53.6% of the population.

Data Collection and Management

The following sections describe the instruments, procedures for data collection, and data management process in this study. This section will also include the data sets used to analyze student proficiency and the collection process used in this study. A timeline is added to provide a visual depiction of scope and sequence used in this study in this study. Finally, this section provides a description of the data management procedures used in this study.

Instrumentation. The records of mathematical achievement on the CST were used in the identification of those with PDM. The CST is the annual diagnostic measure for California's Standardized Testing and Reporting Service. These tests are cumulative reviews of California's content standards for Grades 2 through 11 (California Department of Education Assessment Development and Administration Division, 2013). To develop and ensure CST's validity, reliability, and appropriateness, the California Department of Education (CDE) contracts the Educational Testing Service to develop test items using a multitier process. This process is expected to ensure test items correlate with content standards, are respectful of ethnic and cultural differences, and provide grade and/or course appropriate difficulty (California Department of Education Assessment Development and Administration Division, 2013).

Scale scores provide the number of correctly answered questions, or raw score, for determining the mean of students tested within a given grade or content area. The mean is the average score of all students tested without modification (Division, 2013 Not in references). Scores range from 150 (lowest) to 600 (highest). Further, a score of 300 (basic) and 350 (proficient) identify cut markers across content domains and grade-level expected competencies.

For Grades 2 through 8, CST items are multiple choice and machine scored (California Department of Education Assessment Development and Administration Division, 2013). To ensure test validity, dissemination and administration processes are standardized for uniformity (California Department of Education Assessment Development and Administration Division, 2013). Score keys, specifications, and conversations support effective interpretation of test data processing (California Department of Education Assessment Development and Administration Division, 2013). All data is scanned in accordance with CDE guidelines and merged with demographic data into one detailed report (California Department of Education Assessment Development and Administration Division, 2013).

To compare test scores from year to year, common item response data are referenced using item response theory (California Department of Education Assessment Development and Administration Division, 2013). The CST is calibrated and discerned through linear interpolation and table evaluation (California Department of Education Assessment Development and Administration Division, 2013). Variances in these scores represent discrepancies in student knowledge of the given content or unsystematic errors in the measurement (California Department of Education Assessment

Development and Administration Division, 2013). These scores do not provide parallel evaluation capabilities from year-to-year or account for variance in testing environment or other external factors (California Department of Education Assessment Development and Administration Division, 2013).

District placement exam. The district-designed placement exam represents the collaborative work of several key district staff. This assessment uses state standards, CST-released questions, and instructional experience to mimic the district, state, and federal guidelines for content, content mastery, and grade-level appropriateness. For five consecutive years this test predicted student performance in Algebra I with more than 85% accuracy. Further, proficiency levels consistently align with subsequent CST performance scores in algebra with more than 70% accuracy.

The placement assessment consists of 29 problems covering key sixth, seventh, and eighth grade standards for (a) algebra and functions, (b) number sense, (c) measurement and geometry, and (d) Algebra I content. The district uses two versions of this exam, using the same questions in different order. In addition, this test is taken approximately one month before the statewide assessment for both eighth and ninth grade. The test is administered within a two-week window and taken on a class-by-class basis, using different days during the final academic quarter. Results are itemized and disaggregated to inform instructional stakeholders of pedagogical peaks and valleys in expected skill mastery. Finally, this exam is used for both the initial and summative assessments to suggest the academic placement for subsequent school year.

ALEKS. ALEKS is a comprehensive, web-based, ITS. This advanced form of CAI covers more than 100 academic subjects for millions of students from elementary through postsecondary education. ALEKS uses knowledge space theory (KST), mastery learning, and AI to identify present levels of subject mastery, formatively assess retention of skill mastery, and drive further instruction. This ITS offers bilingual, targeted, and explicit instruction to develop individualized instructional pathways of learning. ALEKS also uses standards-based instruction to support intervention or as a comprehensive class in and of itself.

After a brief tutorial, students take an initial assessment to determine their zones of proximal development. This assessment ranges from 20 to 35 questions and uses an open-ended free response to obtain student content knowledge. The AI constructs a systematic approach to developing individualized instructional pathways for achieving content mastery. These pathways utilize KST to identify students' content knowledge and formulate a plan that supports multiple access points for instruction. A pie chart provides a visual depiction of skill mastery for each domain within a given subject (i.e., numbers sense, algebraic functions, geometry, etc.). For each of these domains, the pie chart also displays skills not yet mastered. ALEKS uses these reference points to provide incremental growth objective for instruction. Working within each student's zones of proximal development, access to the curriculum begins with a click on any slice of the pie.

Instructional design uses state content standards, targeted and explicit instruction, formative feedback, and mastery learning, along with drill and practice to support student learning. ALEKS aligns with state-adopted textbooks for classroom instruction and offers predetermined instructional pathways for content mastery. Educators may modify these paths to fit their specific needs and keep pace with classroom pedagogy. Further, students have the option to select an instructional path based on their given content aptitude or comfort level with a given domain. In the learning mode, teachers have the option to include assignments, and students are given a calendar of instructional objectives. However, students are initially presented with questions based on their knowledge base. With each question and relative to skill requirements, ALEKS provides several tools to support instruction. Directions for each question provide content specific vocabulary. Each vocabulary term includes a hyperlink to its definition. Further, ALEKS offers a dictionary that students may use at their discretion. Also, a calculator is provided for some questions when the content knowledge being assessed does not directly relate to the computation being derived. After viewing the practice problem, students have the option to utilize these tools to solve the given question or seek further instruction via the "explain" hyperlink.

For each question, ALEKS offers a step-by-step explicit description of the required solution process, which is accessible through the hyperlink. ALEKS articulates each step with a visual diagram and written explanation. In some cases multiple or alternative solution options provide additional context. Further, students can print the explanations for their convenience and future use. At this point, students may choose to try a new practice problem within a given content domain or see another example. However, students also have the option to use the internal email and contact their instructional provider for further assistance.

When students decide to attempt a new problem, their response guides the subsequent steps for instruction. Moreover, ALEKS artificial intelligence engine continues its use of free response methodology to identify content knowledge. A student who answers the question correctly is given formative feedback. He or she then moves on to a similar problem. This process continues until the student has answered at least three or more consecutive questions correctly. Next, the student ascends to the next incremental benchmark for further development, and the pie chart of skill mastery is updated. The skills mastered are added to the student's review bank and archived for future formative assessments.

If a student answers the practice problem incorrectly, formative feedback guides him or her to review the explanation. The student is then offered the option of seeing another example or attempting a new problem. This process continues with each incorrect answer. However, ALEKS now requires a more comprehensive description of the student's mastery.

Each wrong answer triggers up to four specific responses. First, the number of consecutive correct answers needed to ascend increases. Second, with consecutive wrong answers, ALEKS scaffolds the instructional content down until it finds a zone of proximal development. Third, after several incorrect answers, the student is guided to a supporting skill that ALEKS suggests may aid in developing mastery of the current content. Finally, the pie chart is amended to reflect ALEKS's most recent assessment of the student's skill mastery.

Supportive to the practice questions provided, ALEKS also includes multiple platforms for review. Previously mastered skills are routinely reviewed for their retention. However, students may choose to access their reviewable skills at their discretion. Individualized worksheets offer further review. These worksheets represent a comprehensive review of mastered skills. Further, by being computer generated, worksheets support daily intervention for the development of retention. ALEKS also allows educational providers the option to develop worksheets based on their instructional requirements for each student and within their zones of proximal development.

Formative assessments are generated periodically in the form of quizzes. Mastered content is assessed to assure retention. These quizzes, much like the initial assessment, inform mastery assessments and add significant data to suggest a student's content knowledge. In addition, instructional providers may generate quizzes to align with classroom instruction. Quizzes also avoid multiple-choice answers with the free-response answers.

Beyond the formative feedback and the skills mastery assessments, ALEKS provides educational stakeholders with multiple dimensions of diagnostic descriptions to guide pedagogical development. They may also choose to generate their own reports for an individual, group, class, or school. Students along with other educational stakeholders may access detailed reports on the state content standards practiced, mastered, and not yet addressed.

ALEKS also calculates significant dimensions of data on engagement time. Educational stakeholders can see which days a student has used ALEKS, for how long, the number of skills practiced, and those they have mastered. Further, ALEKS offers data on the number of skills mastered per hour of instruction. In calculating these temporal markers of performance, the AI attempts to parcel out actual engagement time from that which is perceived as idle.

Along with pie charts, state standards, and time on topic reports, educational stakeholders also have a few other data points to aid in providing data driven instruction. For example, a color-coded bar chart highlights the progress made on the last assessment in learning mode and what is not yet available to the students based on their current content knowledge. Teachers additionally have the option to calculate students' grades based on their instructional guidelines. Further, the AI supports comparisons across each of the previously mentioned instructional modules in generating a relative performance analysis.

For the FCUSD, ALEKS is used as a supplemental tool outside of the formal instruction of algebra. ALEKS is a part of the required intervention course for those who have not shown themselves ready for algebra. Testing at basic or better on the CST, or passing the algebra assessment exam given at the end of eighth grade, determine readiness. Instructional models offer significant differences between school sites and teachers.

Block scheduling is used as the instructional model for site "B." Students attend four classes, for 145 minutes, each day. This schedule rotates three classes, on a daily basis, and maintains one class as a daily homeroom for clerical and informational purposes. The homeroom class is a minimal period of 30 minutes daily. On Fridays, students attend all seven classes and have a 50-minute class period. Sites "A" and "C" maintain a daily 50-minute period for all instructional courses.

Scheduling varies between locations. Regardless of site, students may have the same teacher for algebra instruction that they have for their intervention courses. Some have a different instructor for their algebra course and their intervention course. Some intervention courses follow the algebra course and some do not. Further, for site "B" the daily class rotates and the actual time of class changes.

Application of ALEKS is left to the education providers' discretion. However, guidelines for its use include standardized measures of performance, which are a part of each student's final grade and are derived from ALEKS's AI engine. These include measure of engagement time, skills mastered per week, and progress toward identified goals. Students are expected to complete an average of 210 minutes per week in engagement time. This time is inclusive of set-up, preparation, and shutting down requirements. Students are also expected to master 10 topics a week—averaging two to three each hour. Finally, the progress bar informs instruction of skill retention between assessments. This is graded on a varying scale based on individual performance and relative to past performance. These three constructs are available through ALEKS's reporting system.

Independent variable(s). The independent variable of time needed to learn is measured as a function of student engagement time. Engagement time is measured in minutes.

Controlling variable(s). The controlling variables are gender, grade, socioeconomic level, prior reading and mathematics achievement, and attendance (See Table 1).

Table 1

Categories of Controlling Variables

Academic variables	Demographic variables	Instructional variables
Prior math achievement	Gender	Attendance
Prior reading achievement	Socioeconomic level	

Note: Table 1 categorizes the controlling variables used in this study.

Dependent variables. The dependent variables are final mastery on ALEKS, current GPA, and student achievement on the Algebra I placement assessment when used as a posttest comparison.

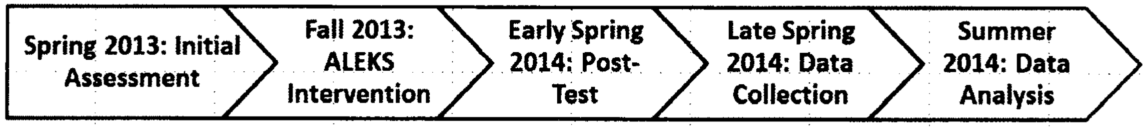
Procedures for data collection. In the fall of 2013, eighth-grade students took the Algebra I initial placement assessment. Scores were used to identify students who would be advised to take the Algebra I intervention as a supplemental course along with their Algebra I general education class. The sample population for this study received ALEKS instruction from September of 2013 through February 2014 for a total of 20 weeks (See Figure 1). Participating students in this study took an initial assessment on ALEKS, which provided a baseline for instruction.

Students were provided weekly class time to practice and develop their skill mastery. Because ALEKS is web based, students also could access their instructional portal outside of class. General expectations were for every student to complete an average of 600 minutes of engagement time and master 10 skills per week. Periodically, and based on individual readiness, ALAKS conducted formative assessments to determine cumulative skill mastery. The ALEKS AI collected data representative of actual time engagement relative to prior individual performance, skill mastery, skills practiced, and skills mastered per hour of instruction.

In the March of 2014, the ninth-grade students who had taken the Algebra I initial assessment took the same exam again (See Figure 1). Students were provided an alternate version of the exam; however, the questions were the same. Scores were scanned into the district database for future evaluation. After receiving permission from the internal review board to conduct this study, the district ALEKS coordinator was instructed to retrieve the relevant data. Data collection was conducted over a two-month period, between March of 2014 and May of 2014 (See Figure 1). Both the district and ALEKS data were provided via email.

Figure 1

Timeline of Research



Management strategies. Only archival data were used in this study. Data were provided on Excel worksheets. To ensure anonymity, no names were provided. Any information provided by FCUSD was stored in an encrypted file on a password-protected computer. Students' names were excluded from all data. Only identification numbers were used in coding. Further, any identifying descriptors of the district were removed from the data provided and this articulation.

Data Analysis and Interpretation

The following sections explain the methods used to determine the nature of the relationship between engagement time and student achievement for those with PDM. This includes the identification of descriptive measures of central tendencies used to suggest probable relationships, the positive or negative relationships existing between variables, and the inferable prediction the data would suggest. In addition, an explanation of the procedures taken to ensure validity is also provided.

Descriptive statistics. This study will look at measures of central tendencies to help explore the relationship between time spent on task and achievement. The goal here is to provide a framework of participant performance (Bickman & Rog, 2009). This study will present information on the average (or mean) time spent by participants on ALEKS. In consideration of the sample size and non-normal distribution, a *z*-score will be calculated, which will allow the calculation of a normal distribution (Field, 2009). Additionally, this study will collect data on the median, the most frequent amount of time spent, the range, and standard deviation from the mean. These statistical attributes will provide comparable data for evaluating performance throughout the study. Also, this will include data from pretest evaluations, ALEKS, and posttest achievement data.

Correlation. By analyzing the correlations between variables, this study hopes to examine what relationships exist between engagement time, achievement on ALEKS, and on the district-designed posttest. In consideration of the normalize distribution seen in with most variables, this study uses the Pearson's correlation method, unless otherwise stated, to assess the given relationships (Field, 2009). However, it should be noted that the presence of a correlation does not suggest a causal relationship between variables. This analysis simply denotes whether the relationship, if one exists, is positive or negative (Field, 2009). Therefore, the foci for analysis were to discern the characteristics of the relationship between engagement time and student performance on the district-adopted posttest measures for those with PDM.

Regression. This study will use regression analysis to conduct an evaluation of the given model, in consort with given errors, enabling predictions about the desired outcome (Field, 2009). This study will present the following conditions to analyze the given data.

Controlling for gender, free/reduced lunch eligibility, previous reading achievement, previous math achievement, and attendance what predictions can be made about the use of ALEKS, as an intervention, with student algebraic proficiency? The model is described as follows:

$Y = b_0 + b_1X$ (gender) $+ b_2X$ (free/reduced lunch)

$+ B_3X$ (reading achievement) $+ b_4X$ (math achievement) $+$

B_5X (attendance) $+ b_6X$ (intervention) $+ \boldsymbol{\varepsilon}_i$

$Y=$ Achievement outcomes

$b_0 =$ Interception of time and achievement

$b_{1\text{-}5} =$ sex, socioeconomics, previous reading achievement,

previous math achievement, attendance $X_{711}b_1$

$X_6 =$ Time engagement (in minute increments)

$\varepsilon_i =$ Error (everything else not explained by the model

$Xi =$ Time engagement

Procedures to ensure validity. This study will utilize statistical norms, correlation, and regression algorithms to analyze data. There are typically some internal and external validity errors associated with such studies. While this study will utilize all possible participants available, several students will not meet the requirements to participate. This will cause some variance from the mean. Thus, the size of the given sample does not support the generalization to other populations outside of the given district. However, studies like this must seek to analyze programs to determine their efficacy of use.

To perform the statistical analysis and address issues of internal validity, this study used IBM's Statistical Package for the Social Sciences (SPSS) Standard modular software. Since the 1970's, versions of SPSS have allowed researchers to conduct accepted research in many fields of study, including educational research (Field, 2009; Zagumny, 2001). SPSS supports the use of metadata to conduct a wide range of analysis, including measures of central tendencies, correlation, and regression. Further, SPSS constrains data to identify one-to-one and one-to-many relationships between variables (Field, 2009). This module also supports the development of simulations and other customizable features to perform valued quantitative analysis of variables.

Role of the researcher. This study focused on archival data provided by the FCUSD. The researcher in this study does not work for the district, or any of its educational partners. At no time did the researcher participate, interact, or instruct participants in the sample or their educational providers on the expectations of engagement or performance. Further, the researcher provided no expectations to the district representative with regard to student performance. The role of the research consisted of establishing contact with the district of study and requesting archival data, which offered no audience for bias.

The SPSS module was chosen by the researcher for its ability to analyze the data obtained in this study. It was also selected for its capacity to work with raw metadata, as opposed to other software modules requiring modifications to the data for comprehensive procedures. Further, the analytical acceptance of the software influenced the decision of the researcher in the hope of securing valid, reliable, and reproducible outcomes aligned with the present body of research in this field and the needs of the local educational leadership.

Chapter Summary

In summation, the development of mathematic proficiency is a key factor in the life and human capital a person may achieve (Ashcraft & Krause, 2007; Balfanz, 2009; Heckman & LaFontaine, 2010; Jordan, Hanich, & Kaplan, 2003; Maccini et al., 1999; Miller & Mercer, 1997). For those with PDM, the present pace and opportunities to learn limit the effectiveness of instruction on student outcomes (Allsopp et al., 2010; L. S. Fuchs, Mock, Morgan, & Young, 2003; L. S. Fuchs et al., 2010, 2012; L. S. Fuchs & Fuchs, 2009; L. S. Fuchs, 2009; Gersten, Chard, et al., 2009a; Watson & Gable, 2013). This dissertation seeks to describe the relationship between engagement time for those students with PDM, and instruction when using an ITS. This study focuses on the extent of instructional engagement time and perseverance in skill acquisition as the independent variable influencing student achievement. Chapter 3 covered the methodology, research design, setting, sample, instrumentation and data collection, data analysis, and procedures to ensure validity of this proposed study. Additionally, this chapter described and explained the archival data collection process used in this study and thoroughly described the data analysis plans. Finally, limitations were discussed.

CHAPTER 4

FINDINGS

This study uses quantitative methods to analyze archival data on ninth-grade student performance in mathematics. The methodology chosen was a cross-sectional approach to evaluate the effects of engagement time on the student performance for those with PDM. The sample of students was taken from three high schools ninth-grade classes in FCUSD. The sample of 138 students was identified using prior mathematics achievement and participation in a supplemental math course using ALEKS during the 2013-14 academic year. The sample was also representative of the lowest quartile of academic performance on the California Standardized Test of achievement. Archival data was collected over a two-month period from March 2014 and May 2014 to disaggregate the given sample and evaluate the effects of engagement time with ALEKS. To evaluate the performance of students with PDM, this study uses measures of central tendencies, correlation of associated variables, and multiple regression analyses. Multiple regression analysis controlled for gender, socioeconomic level, attendance, prior math achievement, prior reading achievement, and performance on ALEKS. The independent variable evaluated in this study was engagement time measured in minutes. The dependent variables evaluated in this study were Algebra I post assessment, GPA, and ending mastery on ALAKS. The following sections provide the results for this study.

Research Question

With the increased demands for educational proficiency (National Mathematics Advisory Panel, 2008), those with PDM face progressive expectations, which raise the instructional hurdles already impeding their school learning (Geary, 2011b; Miller & Mercer, 1997). To address this problem, research has focused on finding and understanding which variables influence learning. Under Carroll's (1963) model of school learning, the time and perseverance needed to learn, as well as the ability to learn, offer quantifiable variables through which to analyze school learning. Educational stakeholders also have sought to meet the growing needs of academic achievement with technological solutions (Allsopp et al., 2010; L. S. Fuchs et al., 2006). However, there are limitations to the understanding of PDM and how the use of technology can address the needs of affected students (Watkins & Gable, 2013).

Students with PDM compose a small segment of the academic population (Geary, 2011b). Further, the overlapping variables causing PDM, the limited understanding of mathematics disorders, and the tendency of prior studies to include both students with PDM and their TA peers inhibit conclusive identification of the variables impeding school learning (Watson &Gable, 2013). This study sought to add understanding of the relationship between time-on-task and educational technology by asking What effect does engagement time with ALEKS have on student performance for those with PDM?

Measures of Central Tendency

The sample population consisted of 138 students in the ninth grade, covering three school sites, which were representative of the lowest quartile of academic performance on the CST for mathematical achievement. The average GPA was 1.95 for these students in the ninth grade. The sample comprised 72% Latino students, 28% African Americans, three Caucasians and Pacific Islanders, and two of Asian descent. Further, 46% students are female and 54% are male (See Table 2). A subset of the sample, 129 students, receive free or reduced-price lunch as a form of financial assistance. An additional nine students pay for their own lunch. The following sections provide measures of central tendencies for the described sample.

Table 2

Demographic Data

	Total number of students	Percent of total
Asian	2	1.4
Pacific Island	3	2.2
Latino	99	71.7
African American	31	22.5
Caucasian	3	2.2

Identification measures. To identify students, this study used CST scale scores, the district-adopted Algebra I initial assessment, and the initial skills mastery score provided by ALEKS. Eighth-grade scale scores were the first measure used to identify students in the sample. Students performing at or above 300 on the mathematical portion of the CST were eliminated from the sample. The mean scale score was 272.97 with a standard deviation of 21.93. Scores ranged between 203 and 299.

To support the identification of those with PDM, this study used the test results from the seventh-grade CST mathematics scale scores and/or the results from the Algebra I initial assessment to further discern persistency of deficit. Students were confirmed by either a seventh-grade scale score below 300 or by achieving less than 19 (62%) correct points, out of a possible 29, on the Algebra I initial assessment. On the CST, the given sample provided a mean scale score of 304.53, with a performance range between 150 and 413 points, and a standard deviation of 52.15 (See Table 3). On the Algebra I initial assessment, the sample had a mean score of 10.17, a range of scores between 3 and 18 points, and a standard deviation of 3.11 points (See Table 3).

Table 3

Measures of Central Tendencies

	Minimum	Maximum	Mean	SD
Current GPA	0.00	4.00	1.95	0.89
Math scale score	150	413	304.53	52.15
ELA scale score	220	467	319.50	45.38
ELA scale score9	223	434	316.23	41.35
Initial mastery (%)	0.05	56.87	11.50	9.82
8th grade CST math	203	299	272.97	21.93
Points correct on initial assessment	3.00%	18	10.17	3.11
Total Time	46.00%	1975	901.81	500.68
Skills per hour	1.04	7.83	3.67	1.38
Ending mastery (%)	2	62	24.08	13.34
Points correct on posttest	1.00%	26	12.87	4.96

Note: The above table provides measures of central tendency for variables used in this study

ALEKS measures. Several measures within ALEKS were also used to characterize the performance of students with PDM. Measures of central tendencies were calculated to describe the interaction between students and the ITS with regard to proficiency. For example, initial mastery on ALEKS identifies students' current level of understanding of the given curriculum. However, it does not offer a homogenous comparison of skill mastery. More specifically, the level of mastery represents a cumulative picture of all the skills taught within a course. Since the instructional pathways for a given curriculum vary among students, equivalent scores do not represent the development of comparable skills. Further, ALEKS's initial assessment converts students' performance to a percentage of the assigned curriculum and within an individual's zone of proximal development. It does infer, however, a student's understanding of the given curriculum relative to their individual ability. For the 138 students in this study, the average initial skills mastery was 11.5%, with a range of less than 1% (0.05%) to 56.87%, and a standard deviation less than 10% (9.82%; See Table 3).

Based on the individualized instructional pathways identified by the initial skills mastery, students with PDM were further characterized by (a) the number of minutes they were engaged with ALEKS, (b) the average number of skills mastered per hour for the entire course, and (c) their ending skills mastery. With regard to engagement time, the general expectations were the completion of 180 minutes and mastering 10 skills per week, including start-up and shutdown time. The intervention using ALEKS covered 20 weeks. In general, for the length of the intervention, district expectations were the completion of 2500 minutes and 130 skills mastered, or the equivalent of 3.25 skills mastered per hour.

This study considers engagement time, which represents time-on-task and skills mastered per hour, indicative of a student's ability to learn. Students in this sample spent an average of 894.23 minutes engaged with ALEKS. The range of engagement time was between 46 and 1929 minutes. The median engagement time was 884.54, with standard deviation of 501.66 minutes (See Table 3). For the length of this study, the sample population mastered an average of 3.67 skills per hour. The range of performance was between 1.04 and 7.83 skills mastered per hour. The median was 3.51 skills mastered per hour, with a standard deviation of 1.38 (See Table 3).

Measures of dependent variables. To better understand the growth in proficiency derived from the use of ALEKS with students having PDM, this study used ending skills mastery and the Algebra I posttest measures. Ending mastery represents the growth in understanding that a student achieves within their assigned curriculum. This measure is provided in percentages and represents the amount of the curriculum a student retained as of their last formative assessment. In addition, Algebra I is used to determine the growth in algebra proficiency. The same exam used during the 2012-13 initial assessment was used here as a posttest measure in 2013-14.

Ending mastery on ALEKS and the Algebra I posttest provided measures of central tendency representative of the school learning. For mastery, the average posttest score was 24.08%, with a range of 2% to 62% (See Table 3). The median score was 21.34% and standard deviation of 13.34%. On the Algebra I posttest measure, the mean score was 12.87 points (See Table 3). Scores ranged between one and 25 points correct. The median score was 12 points correct and the standard deviation was 4.96 (See Table 3).

Measures of English language performance. Research has not clarified the relationship between mathematics and reading difficulties. In previous research, where reading difficulties positively correlated with mathematics difficulties, results were representative of elementary students with MLD (Beal et al., 2009; Vukovic, 2012; Vukovic, Lesaux, & Siegel, 2010). For the sample used in this study, these parameters may not effectively characterize their relationships between mathematics and reading ability. To these ends, this study used prior CST ELA scale scores to inform the description of those with PDM and as a control variable in the analysis of student performance.

For the ninth-grade students with PMD used in this study, seventh- and eighth-grade CST scores characterized English proficiency. For the seventh grade, students ELA proficiency had mean scale score of 319.5 and scores ranged between 220 and 487 (See Table 3). The median score was 317 and provided a standard deviation of 45.38 (See Table 3). In eighth grade, the average scale score was 316.23 and the range of scores was between 223 and 434. Their median scale score was 320 and the standard deviation was 41.35 points (See Table 4).

Correlation

The focus of this study was to better understand the relationships between engagement time and student performance. The following section outlines the data analysis conducted to identify significant correlations between dependent, independent, and controlling variables. Relationships with ALEKS ending mastery are also provided. Table 4 provides data on the relationships between the control variables and the Algebra I initial and post assessments. Analysis of the data suggests a significant relationship between the eighth-grade CST math scale scores with the initial (r = .268; p = .001) and post (r = .249; p = .003) assessment measures of mastery on ALEKS (See Table 4). Note, engagement time offered no significant relationships with any of the control variables (See Table 4).

Table 4

Correlation Coefficient

	Free/reduced lunch	Days absent	Initial assessment	Math CST 8th Grade SS	Total time on ALEKS	Skills mastered per hour	Ending mastery	Current GPA	Post assessment
Gender	-.246**	-.118	.008	-.101	-.019	.071	-.027	-.094	-.036
	.004	.169	.927	.239	.829	.406	.751	.271	.672
Free/Reduced Lunch		.094	-.014	.130	-.071	.002	.048	.196*	.058
		.271	.869	.129	.406	.982	.573	.021	.496
Days Absent			-.026	-.015	-.056	-.070	-.107	-.212*	-.068
			.761	.863	.513	.416	.210	.012	.426
Initial Assessment				.268**	-.016	.139	.247**	.216*	.358**
				.001	.853	.104	.003	.011	.000
Math CST 8th Grade SS					.055	.061	.330**	.174*	.249**
					.525	.477	.000	.041	.003
Total Time on ALEKS						.085	.071	.061	.137
						.324	.405	.477	.109
Skills Mastered Per Hour							.473**	.413**	.285**
							.000	.000	.001
Ending Pi Mastery								.400**	.421**
								.000	.000
GPA									.302**
									.000

ALEKS's correlation to performance. The ITS ALEKS provided several significant correlations to student performance. In this analysis, table 4 highlight engagement time providing no significant correlation to either ending mastery or the Algebra I post assessment. However, ending mastery presented a significant data point in its relationships with other performance variables. While a correlation with the initial mastery on ALEKS was expected ($r = .247$, $p = .003$), ending mastery provided more significant correlations with both current GPA ($r =$ 421, $p = .000$) and the Algebra I post assessment ($r = .400$, $p = .000$). In addition, the largest correlation was between ending mastery and the average number of skills mastered per hour ($r = .473$, $p = .000$).

Regression

Regression analysis was used to provide insight into the significance of the explanatory variables' influence on the dependent variables' outcomes (Field, 2009; Zagumny, 2001). It is often used to make predictions of future outcomes based on prior performance (Field, 2009; Zagumny, 2001). To these ends, regression supports the characterization of associated variables with the analysis of performance within given parameters.

Model summary. This subsection provides data on the variance and standard deviation of student performance for the dependent variables of current GPA, posttest, and ending mastery on ALEKS. The R2 was used in the interpretation of the model goodness of fit to the data. This measure supports an accurate fit of the model to the data by modifying the number of explanatory variables relative to the number of data points within the model. For this cross-sectional analysis, linear regression was used to examine the relationship between variables and student performance. This analysis minimized the characterization of the explanatory variable's effect by controlling for (a) gender, (b) socioeconomic level (represented by free/reduced lunch status), (c) attendance, and (d) eighth-grade CST mathematics scale scores. The following section provides results on the relationship between engagement time (e.g., total time on ALEKS) and the ability to learn (e.g., average number of skills mastered per hour) with the dependent variables of current GPA, Algebra I post assessment, and the ending mastery on ALEKS. This section also includes data explaining the models' fit, the variance between samples, and the explanatory variable correlation coefficients with dependent variables outcomes.

For the 138 students in the given sample, both the R2 value and the standard error were calculated using their current GPA, Algebra I posttest assessment, and ending mastery on ALEKS as dependent variables. The R2 value for current GPA was .291, which suggested that 29% of the variance in their GPA was explained by the model with a standard deviation of 0.77. The model also explained almost 23% of variance in the Algebra I post assessment (as suggested by the R2 value of 0.226) and a standard deviation of 4.476. Finally, the model explained 33% of the variance in ending mastery on ALEKS, with a standard deviation of 11.18%.

ANOVA variability. The analysis of variance (ANOVA) presents statistical models, which compare multiple means to identify significant relationships between variables. In this model, the degree of freedom provides the geometric parameters for the sum of squares by identifying the vector relationships between the variable components analyzed and the number of individual data points. The *F*-ratio of distribution provides a comparison of the sum of squares between variables to discern significance of variability for a given component or the probability of nested relationships influencing variance.

The ANOVA analysis provided the following data on variability for the dependent variables of Algebra I post assessment, GPA, and ending mastery on ALEKS relative to the explanatory variables of: (a) gender, (b) socioeconomic level, (c) attendance, (d) average skills mastered per hour, (e) eighth-grade CST math scale scores, and (f) total engagement time. With regard to the Algebra I post assessment, the resulting mean ($M = 108.773$) was statistically significant, with an $F = 5.430$ and $p \leq .000$. For GPA, the mean ($M = 4.536$) was found statistically significant, with an $F = 7.622$ and a $p \leq .000$. Finally, for ending mastery on ALEKS, the mean ($M = 1161.770$) was statistically significant, with an $F = 9.296$ and $p \leq .000$.

Coefficient analysis. The final analysis done in this study was to determine the significance of engagement time with ALEKS to improve student performance on the dependent measures Algebra I post assessment, GPA, and ending mastery on ALEKS, while controlling for all other explanatory variables used in this study. After controlling for gender, socioeconomic level, initial assessment, eighth-grade CST math scale scores, average skills mastered per hour of engagement time, and attendance, the regression analysis suggested the engagement time on ALEKS is not a significant predictor of performance on the Algebra I post assessment, GPA or ending mastery with ALEKS.

Every one unit of increase in engagement time is associated with .001 unit increase in performance on the Algebra I post assessment. However, the *p* value (p = .142) exceeded the parameters of significance (p < .05; See Table 6). With GPA, every one unit of increase in engagement time is associated with 0.0004828 unit increase in grade. Again, the *p* value (p = .717) exceeded the parameters (p < 0.05) of significance (See Table 6). Finally, every one unit of increase in engagement time is associated with .000 unit increase on ending mastery on ALEKS. Further, the *p* value (p = .804) exceeded the parameters (p < 0.05) of significance (See Table 7). These findings suggest that participation in ALEKS did not yield significant results for Algebra I, GPA, or ending mastery on ALEKS for persistently low-achieving students in the sample.

Table 5

Current GPA Coefficients Analysis

	Unstandardized coefficients		Standardized coefficients		
	B	SE	Beta	t	Sig.
(Constant)	-.623	5.062		-.714	.477
Gender	-.166	.797	-.093	-1.208	.229
Free/reduced lunch	.672	1.613	.186	2.415	.017
Initial assessment	.041	.129	.142	1.836	.069
8th-grade CST math scale score	.003	.018	.074	.957	.340
Skills mastered per hour	.244	.282	.378	5.024	.000
Days absent	-.048	.100	-.208	-2.783	.006
Engagement time	.0004828	.001	.027	.363	.717

Table 6

Algebra I Post Assessment Coefficients Analysis

	Unstandardized coefficients		Standardized coefficients		
	B	SE	Beta	t	Sig.
(Constant)	-5.105	6.218		-1.008	.315
Gender	-.313	.800	-.032	-.393	.695
Free/reduced lunch	.969	1.613	.048	.601	.549
Initial assessment	.464	.129	.291	3.592	.000
8th-grade CST math scale score	.032	.018	.141	1.734	.085
Skills mastered per hour	.808	.282	.225	2.864	.005
Days absent	-.057	.046	-.045	-.572	.569
Engagement time	.001	.001	.115	1.479	.142

Table 7

Ending Mastery on ALEKS Coefficients Analysis

	Unstandardized coefficients		Standardized coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-40.284	12.641		-3.187	.002
Gender	-.999	1.991	-.037	-.502	.617
Free/reduced lunch	.744	4.028	.014	.185	.854
Initial assessment	.489	.322	.114	1.517	.132
8th grade CST math scale score	.161	.046	.266	3.518	.001
Skills mastered per hour	4.220	.705	.437	5.990	.000
Days absent	-.258	.250	-.075	-1.030	.305
Engagement time	.000479	.002	.018	.248	.804

Chapter Summary

In summation, students' prior CST scores in math and English provided significant correlations with the Algebra I post assessment, current GPA, and ending mastery on ALEKS. Further, CST math scores provided a significant relationship with the number of skills mastered per hour. Ending mastery on ALEKS and Algebra I post assessment also provided significant correlations with average skills mastered per hour. However, regression analysis provided no significant predictable relationships between engagement time and the Algebra I post assessment, current GPA, or ending mastery on ALEKS.

CHAPTER 5

DISCUSSION

The variables needed to learn mathematics lack the clarity of influence seen in other subjects (Geary, 2011b; Miller & Mercer, 1997). With students' having PDM, the cognitive complexities further aggravate the capacity of traditional measures to intervene (Gersten et al., 2009; Miller & Mercer, 1997). For students with PDM these variables create a glass ceiling to human capital. To these ends, research seeks viable pedagogical solutions to improve instructional practices and the potential quality of life for students with PDM (Gersten et al., 2009; National Mathematics Advisory Panel, 2008).

Technological solutions offer a number of viable resources that support the instructional needs of the individual (*Mandl, & Lesgold*, 1988). However, for students with PDM, the instructional benefits to improve students achievement remains inconclusive (Gersten et al., 2009). Further, the application of educational technology adds more impediments to the learning process by adding the need to engage with the medium. By discerning which variables of technological engagement improve student learning, research improves the instructional practices for students and policy.

The time needed to learn presents a common vector for analysis with both variables of learning and the use of technological solutions (Carroll, 1963). By identifying the amount of time needed to learn under a given condition, educational stakeholders gain valuable knowledge on a significant variable of the learning process. The temporal demands placed on instruction make the optimization of engagement time crucial to the selection of mediums and the development of policy and practices for implementation.

The purpose of this study was to understand the influence of engagement time on performance for students' with PDM. The instructional medium used in this study was the intelligent tutoring system ALEKS. This study sought to explain the effect of engagement time on performance when using ALEKS for students with PDM. To these ends, this study conducted quantitative cross-sectional analysis of archival data on ninth-grade students taking Algebra I and receiving supplemental instruction using ALEKS during the 2013-14 academic year. The sample used in this study also represented the lowest quartile of achievement showing persistent poor performance over time, testing in the below and far-below basic range of mathematical ability on the CST for both their seventh- and eighth-grade academic years.

The following sections provide the interpretation of results derived from this study, which include the conclusion, implications, and recommendations. These sections discuss the results of this study in terms of prior research, policy, practice, and theory. Further, the following sections give recommendations for future research. Finally, this section provides a closing summary of the most significant points from this study.

Conclusions

This evaluation of archival data to better understand the influential variables on performance for students with PDM revealed several noteworthy associations. Most notably, engagement time offered no significant relationships with ending mastery on ALEKS, current GPA, and Algebra I post assessments. Traditional measures of significance, like those established by Cohen, Kulik, & Kulik, (1982) seeks treatment effects capable of influencing identifiable change for one in 20 cases (.05%) to qualify as a substantial difference (Lipsey et al., 2012). However, treating such parameters as absolutes suggests optimal and homogeneous treatment conditions produce equally homogeneous results. As Geary (2011b), Miller and Mercer (1997), Murphy et al., (2007), along with Watkins and Gable (2012) note, when parameters for the ability to learn are provided with narrowly defined margins for comparison, the value and identification and interoperations of variables influencing interventions become marginalized. Assumptions of this nature devalue the severity of the academic deficit by implying that results that improve the quality of life for the one in 20 individuals lacks sufficient value and practicality for continued implementation. Lipsey et al., (2012) contend that for students facing significant learning hurdles, traditional measures of effect can underestimate the significance of the intervention relative to their needs, individual abilities, and the capacity of the intervention to close the achievement gap. This study focused on the benefit to the student relative to the potential of the variable.

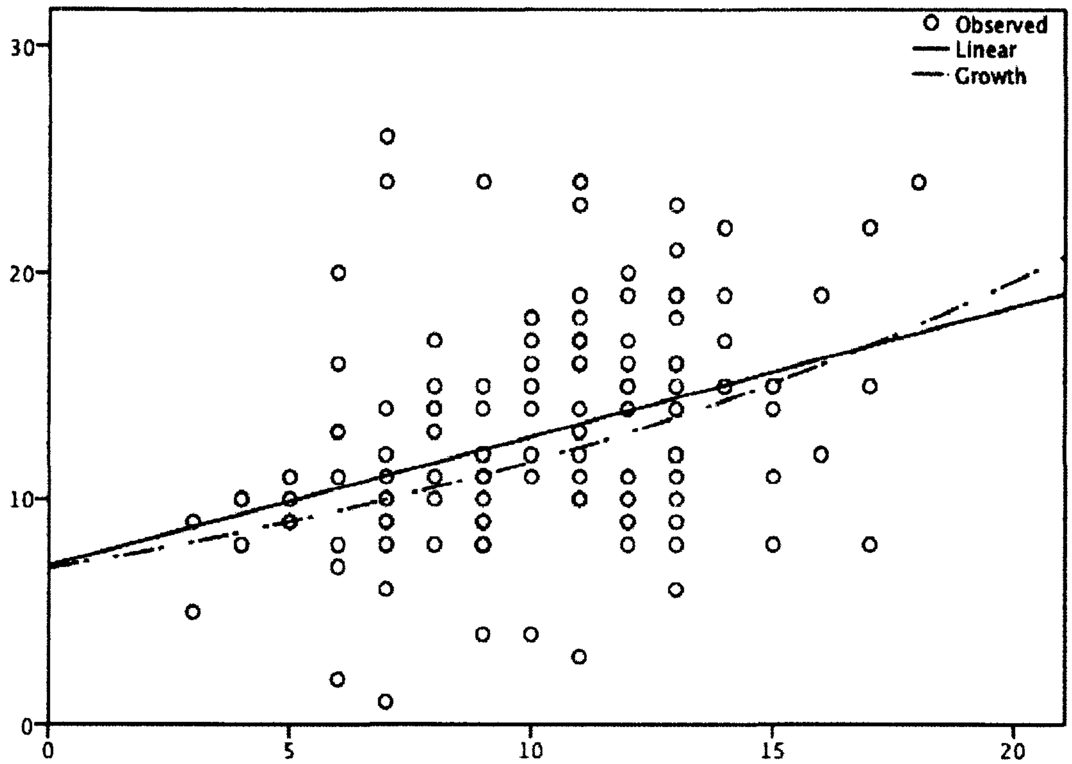


Figure 2. Pretest to posttest performance growth

To add context, the following section offers a comparison of descriptive statistics with the other students who took both the Algebra I initial assessment and Algebra I post assessment in Table 8. This comparison does not attempt to suggest causation or alter the statistical magnitude of the measures provided by the sample population but rather to add an objective framework for viewing the effects of ALEKS within the learning conditions. When juxtaposed with students who also used ALEKS (but did not meet the criteria for qualification in this study) and those who did not receive any intervention, students' with PDM who used ALEKS made moderate gains toward closing the achievement gap. Comparisons of means, from pretest to posttest, show students' with PDM saw the greatest gains in mean score (26%), relative to their peers. Students who also used ALEKS over the same time period increased their mean score by 8%, and their peers who received no intervention improved their average performance 2%. Further, for the other students who used ALEKS from pretest to posttest, the standard deviation remained constant. The most telling data came from those with no intervention. While students in the sample incrementally increased their mean score and provided a maximum score of 26 out 29, those with no intervention expanded the range in performance (26), saw their maximum score decrease from 28 to 26, and provided a larger standard deviation than those in the sample population. These statistics suggest the nominal growth seen through measures of central tendency, for students' with PDM using ALEKS, offers some significant markers of the attrition to the achievement gap for these students (See Table 8).

Table 8

Comparative Performance Outcomes

		N	Range	Minimum	Maximum	Mean	*SD*
Sample population	Initial	138	15	3	18	10.17	3.108
	Post	138	25	1	26	12.87	4.956
Used ALEKS but not in sample	Initial	738	26	3	29	14.77	5.131
	Post	738	25	4	29	16.07	5.131
Only took the pre & post test	Initial	38	22	6	28	14.08	5.395
	Post	38	26	0	26	14.39	6.118

The amount of engagement time offered little to no significant benefit for students' with PDM. However, students were expected to complete at least 3,500 minutes. In practice, students averaged a little more than 900 minutes over the 20 weeks of intervention. In comparison, Campuzano et al. (2009) conducted a two-year evaluation of Larson Algebra I. Students used the ITS roughly 1300 minutes in year 1 and 1400 minutes in year 2. Students average effect sizes on the year-end-standardized assessment were -.02 ($p > .50$) in year 1 and .15 ($p = < .03$) in year 2. In comparison, this sample group provided positive, yet not significant, correlations between engagement time and ending mastery on ALEKS ($r = .071$, $p = .405$), current GPA ($r = .061$, $p = .477$), and Algebra I post assessment ($r = .137$, $p = .109$).

Given the lack of fidelity in engagement, the relative performance in Campuzano et al. (2009), and the substantial correlation between ending mastery and average number of skills mastered per hour ($r = .421$, $p = .000$), results suggest engagement time may exist as a dependent variable of pedagogical practice for students' with PDM. Students often attempt to fool computer-based mediums by using every possible answer until the system moves them forward (Baker, Corbett, & Koedinger, 2004). In addition, they seek help with problems without exacerbating their own mental recourse (Aleven, 2013; Aleven, McLaren, Roll, & Koedinger, 2006; Aleven, Stahl, Schworm, Fischer, & Wallace, 2003; Beal, Qu, & Lee, 2008). Further, while the adoption of technology has won over the political checkbook, adoption in the hearts of the instructional providers facilitating its use seems tentative (Alkahtani, 2013; Allsopp et al., 2009; Campuzano et al., 2009; Crawford et al., 2012; Fagnano & Schacter, 1999; Mautone, DuPaul, & Jitendra, 2005). Therefore, fidelity of implementation subjectively depends on pedagogical convictions to implement objectively. In consequence, effect size and learning outcomes depend on instructional environments vested in meeting the instructional expectations.

Campuzano et al. (2009) found a significant gain from year 1 to year 2, in both effect size and engagement time. This suggests experience with the medium exist as a significant variable of influence when using an ITS. Further, These results support Ding and Davison's (2005) assertion that gains in growth rate offer a better identifier for effect than scale scores alone. With this in mind, future longitudinal model studies assessing both standardized and curriculum measures may offer greater insight into the variables influencing instruction, like engagement time.

The regression analysis suggested even less of a relationship with ALEKS than the measures of either central tendency or correlation. Moderate effect sizes with mathematical interventions using educational technology typically produce less significant results than their academic content counter parts (Cheung & Slavin, 2013). In Campuzano et al.'s (2009) large scale randomized trial, the effect size was +0.03. Cheung and Slavin's (2013) meta-analysis on the effectiveness of educational technology found a cumulative effect size of +0.16, with supplemental use of technology providing the most predictive effect size of + .19. With more advanced technologies, like *Cognitive Tutor* (-0.04) and *I Can learn* (0.16), the effect size was minimally predictive of student performance. Slavin, Lake, & Groff's (2008) meta-analysis found average effect size of +0.10 over 38 studies using a CAI.

In this study, engagement time offered no significant effect on student performance for ending mastery on ALEKS (β = .00048, p = .804), current GPA (β = .000483, p = .717), and Algebra I post assessment (β = 001, p = .142). Several factors, however, impede the effective evaluation of engagement time in this study. Most egregiously, engagement time was a calculated requirement of their class grade and required 2500 minutes on ALEKS to obtain 60% of their total grade for each of the school sites. With none of the students in this study coming within 500 minutes of that mark, a mean score of 900 minutes, a SD of over 500 minutes, and an average GPA for students in the sample slightly below a 2.0 raises the question, "what relevance was placed on engagement with ALEKS and completion of academic requirements?

Successful integration of technological solutions requires and depends on systematic integration, presentation, and support within the context of instructions (Allsopp et al., 2010; D. Fuchs et al., 2003; L. S. Fuchs, Fuchs, & Compton, 2013; Gagné & Merrill, 1990; R. Gersten, D Chard, et al., 2009b; R. Gersten, D. J. Chard, et al., 2009; Miller & Mercer, 1997; Montague, Enders, & Dietz, 2011; Slavin et al., 2009). For example, in Cheung and Slavin's (2013) review of educational technology, studies in which students participated in more than 30 minutes of engagement time per week produced a greater effect size from its use. The lack of alignment between identified temporal objectives of engagement time and student performance suggests a fundamental breakdown in delivery. Further, the moderately positive results provided earlier, which is counterintuitive to these effect sizes, suggests a modicum of learning that cannot be attributed to traditional instruction alone. In addition, the sample size was greatly reduced because of limited available data. This further skewed the interpretation of the effect and influence of engagement time. In addition, the fact this study used cross-sectional analysis supports the ideology underlying the focus of this paper to better understand the influence of engagement time; however, the lack of a control group and comparison group for analysis significantly reduces the validity of results with similar parameters of discovery (Doran & Izumi, 2004; Else-Quest, Hyde, & Linn, 2010; Montague & van Garderen, 2003; Swanson, 2006). However, the regression analysis did find one significant predictor variable, emphasizing the influence of time to improve student performance: the number of skills mastered per hour while using ALEKS.

On average, students in the sample group met the instructional expectation of skills mastered per hour, suggesting the base requirement of 3.5 skills per hour was a reasonable expectation. In addition, the number of skills mastered per hour on ALEKS also offered the most significant correlations with student performance. Ending mastery on ALEKS (r = .473, p = .000), current GPA (r = .400 p = .000), and Algebra I post assessment (r = .421, p =.000) had significant relationships with the number of skills mastered per hour, suggesting the number of skills mastered per hour offer probable predictors for student performance in math.

In addition, among the performance variables, ending mastery on ALEKS and current GPA also possessed significant relationships with the Algebra I post assessment. Ending mastery on ALEKS and current GPA possessed a significant correlation in performance (r =.413; p = .000). This suggests ending mastery on ALAKS offers a probable predictor for current GPA. Further, ending mastery on ALEKS also possessed a significant correlation with Algebra I post assessment (r =.285, p = .001). This suggests ending mastery offers a possible predictor for Algebra I post assessment. Finally, current GPA also possessed a significant relationship with Algebra I post assessment (r = .302 p = .000), suggesting a student's current GPA offers possible predictors for the Algebra I post assessment.

Finally, neither gender, socioeconomic level, nor attendance provided significant correlations with ending mastery on ALEKS, current GPA, or the Algebra I post assessment. This would suggest that for students with PDM, these control variables offer no insight into their ability to perform in mathematics. However, with eighth-grade CST mathematics scale scores, a significant relationship existed for each of the performance variables.

The most telling variable evaluated in this study was ending mastery with ALEKS. Ending mastery provided significant and informative correlations with the eighth-grade CST for mathematic achievement (r = .300, p = .000), the current GPA (r = .400, p = .000), and the Algebra I post assessment (r = .421, p = .000). This would suggest that the ending mastery data set exists as a significant variable for making predictions of future performance. While the regression analysis offered no significant support of this, there seems to exist a path of predictable success relating the two data sets if the instructional environment were compromised by a lack of fidelity in implementation.

Results suggest for every one unit increase in skill mastered per hour, it is reasonable to expect .808 increase in ending mastery (p = .005). Given the relationship with performance measures already established by correlational statistics this implies that the greater number of skills mastered per hour by students' with PDM, the greater instructional gains they will receive. When synthesized with the conceptual understanding, established in this paper by Campuzano et al. (2009) and Ding and Davison (2005) that statistical analysis of gains, over time, offer a greater evaluation of efficacy with treatment on students' development, it seems reasonable to expect incrementally better performance next year and further reduction of the achievement gap from baseline performance. Further, the lack of fidelity in implementation suggests the value added by the ending mastery could be greater with dedication to implementation.

Implications

This study was a single subject, cross-sectional analysis of archival data, on students' with PDM, which limits the applicability of results outside of the sample. Generalization of results, however, was not the purpose of this study. Rather, this articulation sought a better understanding of the influence engagement time has on student performance while using ALEKS as the instructional medium for intervention in Algebra I. The implications here attempt to inform theory, policy, and practice by discerning quantifiable descriptors of efficacy by (a) defining student performance, (b) characterizing possible correlations between engagement time and beneficial conditions, and (c) evaluating the parameters of interpretation within context for instruction relative to the given sample.

The historically moderate-to-inconclusive results seen in a number of studies apply statistical norms to identify the effectiveness of treatment (Lipsey et al., 2012). To derive a valid effect, researchers remove outliers and focus on those students around the mean. For students with PDM falling outside this range of consideration, standardized results do not adequately represent their ability to learn or the associated effect of treatment (Geary, 2011b; Cheung & Slavin, 2013; Miller & Mercer, 1997; Watkins & Gable, 2013). A paradigm shift in how stakeholders view results, for these students, might improve interpretation and policy decisions. Samples that better represent the abilities, aptitudes, and instructional models of at-risk subgroups may offer a better model of norms for viewing study results. Future research should look to further defining markers of effect size, which represent specific subpopulations, such as those with PDM.

The suggested incremental growth seen in the measures of central tendencies, significant correlations between skills mastered per hour, measures of performance, and the no significant positive effect sizes reflect typical results seen in studies assessing students' with PDM. Carroll's (1963) model of school learning theory views the efficacy of instructional mediums as a product of time, ability, and aptitude for the given subject. The persistent poor performance seen in students' with PDM suggests hurdles in ability, aptitude, or temporal needs that should be accounted for when evaluating the efficacy of treatment. Redefining the parameters for which effectiveness is assessed, as seen in this study, offers significant markers of incremental growth for closing the achievement gap, relative to the capacity of the students and the context of instruction. Further, data-driven decisions receive parameters more appropriate for influencing learning with students performing outside normalized conditions. Analytical frameworks accounting for such contextual hurdles support outliers within their zones of proximal development. Future research should look to the variables influencing the number of skills mastered per hour in reference to this specific subpopulation and the use of ALEKS.

In practice, the data in this study imply a need for greater priority placed on the integration of ALEKS. While results here appear insignificant, the relevant positive relationship between ALEKS and student performance solicits further inquiry into the possible results if instructional expectations are met. Further, in Cheung and Slavin (2013), the use of educational technologies to improve performance proved most effective when used as supplemental measure, as in this study. Results in this study suggest a need for continued use of ALEKS as a supplemental measure; however, the lack of academic achievement needs further discovery to improve implementation practices.

Recommendations

Engagement time exists as a fundamental element of the needs, abilities, and pedagogical development of learning (Carroll, 1963). The evaluation of this variable suggests a need for a paradigm shift in how students, such as those with PDM, are viewed. Adjusting the parameters by which we view student performance supports the optimization of policy to support the application of its use. Implementations of practices that ensure students meet expectations and guarantee opportunities to learn should be established. In addition, results from this study recommend the development of instructional practices that prioritize engagement time and protect the opportunities to learn with ALEKS.

Summary of Dissertation

Addressing the needs of those with PDM provides an enigma that becomes further complicated when trying to understand the impact of measures like the time needed to learn (Watkins & Gable, 2013). The use of instructional mediums like ALEKS further convolutes the determination of effect seen from influential variables like engagement time (Allsopp et al., 2010; Cheung & Slavin, 2013; Gersten et al., 2007; Seo & Woo, 2010). To these ends, the purpose of this study was to determine the effect of engagement while using ALEKS for those with PDM.

Results from this study revealed a moderate relationship between engagement time and performance when using ALEKS as an instructional medium. However, by traditional measures of validity, results were no significant. Measures of central tendency revealed incremental growth toward closing the achievement gap anchored by significant positive effect sizes between skills mastered per hour and measures of performance. This suggests that future research focus on () adjusting parameters of valid effect, (b) identification of instructional practices that can optimize the use of ALEKS relative to the number of skills mastered per hour, and (c) the political and practical directives that will value the use of ALEKS as an instructional medium.

The severity of PDM goes beyond the number of mistakes students make. The number of different and inconsistent mistakes students make best describes the condition of those with PDM. The limitations placed on students' ability to learn, their aptitude, and the effect of instruction begs for the development of measures that more effectively represent their performance band and account for their capacity to learn. This study mimicked several previous studies, which showed minimal to no significant results to support interventions under traditional measures of effect. However, the incremental growth seen in this study does suggest further research into the effect of engagement time under more optimal conditions is needed to clarify its effect.

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