COGNITIVE TUTORING AND ASSESSMENT SYSTEMS AND

MATHEMATICS ACHIEVEMENT: A QUANTITATIVE

STUDY OF THE SUMMIT LEARNING PLATFORM

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By
Andrew David Haws

B.A. Mathematics, Truman State University - Kirksville, 2008
M.A. Mathematics Education, Truman State University - Kirksville, 2010
M.Ed. Educational Leadership, Park University - Parkville, 2012

Kansas City, Missouri
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COGNITIVE TUTORING AND ASSESSMENT SYSTEMS AND MATHEMATICS ACHIEVEMENT: A QUANTITATIVE STUDY OF THE SUMMIT LEARNING PLATFORM

Andrew David Haws, Candidate for the Doctor of Education Degree

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ABSTRACT

The purpose of this study was to determine if the Summit Learning Platform, a type of Intelligent Tutoring System, has a positive association with mathematics achievement of high school students in grades nine through eleven. The study was conducted in a Midwest suburban school district among three high schools within the same district. Further, a quasi-experimental research design was used with a sample size of 2000 students in the control group and 450 students in the treatment group. Data were compiled from the 2018-2019 school year and applied a combination of t-tests and analysis of variance (ANOVA) to compare the mean scores of the two groups. As comparison points, the Northwest Evaluation Association (NWEA), pre-ACT, and ACT were used in this Midwest district as measures among all students. The results demonstrated that students using the Summit Learning Platform showed significant gains when using their pre-test and post-test scores, but there was not statistical significance when analyzing the measures between the control and treatment groups. As more school districts utilize technological tools in far-reaching efforts to raise achievement levels in math, the intent of the study was to demonstrate potential benefits of the Summit Learning Platform for districts across the nation.

Keywords: Education, Assessment, Achievement, Mathematics, Summit Learning Platform, Cognitive tutoring

APPROVAL PAGE

The undersigned, appointed by the Dean of the School of Education, have examined a dissertation titled "Cognitive Tutoring and Assessment Systems and Mathematics Achievement: A Quantitative Study of the Summit Learning Platform," presented by Andrew David Haws, candidate for the Doctor of Education degree, and certify that in their opinion it is worthy of acceptance.

Supervisory Committee:

Loyce Caruthers, Ph.D., Committee Chair
Division of Educational Leadership, Policy and Foundations

Tiffani Riggers-Piehl, Ph.D.
Division of Educational Leadership, Policy and Foundations

Dianne Smith, Ph.D., Professor Emerita
Division of Educational Leadership, Policy & Foundations

Jennifer Gross, Ed.D.
Educator, Park Hill School District

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CHAPTER 1

INTRODUCTION

For many students in both secondary and post-secondary institutions, mathematics is a dreaded and difficult subject. Historically, mathematics is one of the most scrutinized content areas because it is tied to district funding and scholarships through students' results on standardized tests. Despite this, only 23% of twelfth graders scored at proficient on standardized mathematics tests (National Assessment of Education Progress [NAEP], 2017). Even though high school graduation rates have been steadily rising, students are not entering college with the skills necessary to be successful, evidenced by the growth of remedial classes for introductory level courses (DePaoli et al., 2018; Smith et al., 2015). Unfortunately, an increasing number of college students leave their K-12 school districts unable to meet the academic demands, thereby necessitating remediation, and those in need of remediation drop out of college at a much higher rate (Diehl, 2017).

Such a disconnect in the competency needed to be successful at the post-secondary level is termed the skills gap, and officials from the local, state, and federal levels have placed an increased focus on mathematics achievement in attempts to close the gap. Of further concern, the curricular struggles are much more pronounced when groups of students are disaggregated from the population. Such a discrepancy has been coined the achievement gap, which occurs when White students outperform other underrepresented groups of students and the difference in average scores is larger than the margin of error (NAEP, 2017). In this study, the underrepresented groups consist of African American, Latinx, Multi-Ethnic and Free- and Reduced-Lunch Qualifying (FRLQ) students. As the work of Flores (2007) demonstrated, there has not been adequate progress made, as "significant gaps in mathematics achievement that have not closed considerably over the last three decades … [and] 91% of African-American and 87% of Latin[x] students are not proficient in mathematics" (p. 30). Additionally, socioeconomic status has been predictive of student success in mathematics and engineering courses, with students in lower income brackets experiencing difficulties in these subject areas (Blums et al., 2016). Although these statistics are harrowing, new technological advances may help close the achievement gap in mathematics by supporting students through a more personalized approach.

To address disparities among students, educational pedagogy has evolved, and technology makes it possible to provide additional opportunities to help students understand mathematical content through immediate feedback. Particularly in mathematics, computer algorithms may effectively determine the knowledge state of a student due to the sequential nature of the content (Falmagne et al., 1990). As a result, there have been countless computer programs that use artificial intelligence to effectively model instruction within a classroom to varying degrees of success, the most popular being Assessment and Learning in Knowledge Space (ALEKS, 2019). Even with the creation of such programs, in 2017 the National Center for Educational Statistics (NCES) found that more students have trouble within mathematics courses than any other discipline. Due to this continual struggle throughout all levels of the educational system in the United States, there is a need to evaluate additional cognitive tutoring software which will provide more relevant feedback to discern its potential to positively affect mathematics achievement.

Problem Statement

Many schools attempt to address the achievement gap in mathematics through cognitive reform and deemphasize the affective needs of students. Further, there is often a misunderstanding of the implementation of reforms themselves, which creates a situation in which a school cannot effectively personalize changes for the staff and students it serves (Barieva et al., 2018). If a school is to be effective, however, it must attempt to expand content differentiation while focusing on non-curricular skills (Snape, 2017). Nonetheless, districts tend to focus more on the changes to policies and programs rather than their epistemological and pedagogical functions (Spillane, 2000). In this study, nine different districts were analyzed with 165 interviews conducted to determine why mathematical reform efforts were unsuccessful. Ultimately, the researchers discovered that 80% of district leaders within these schools emphasized form-focused understanding among students. In essence, this type of teaching method is cognitive in nature and "preserve[s] the conventional view of mathematics as teaching procedural knowledge" (p. 154). The more successful reform efforts were function focused, emphasizing collaboration and real-world interaction. This approach not only supported content area knowledge but also tapped into the affective needs of students. Taking these small steps to focus not only on content but also on how a student feels about learning the material supports students' affective domain, which impacts how and what can be learned (Guy et al., 2015). Further, if schools are truly seeking to positively impact the gaps in achievement, pervasive among groups of students based on gender, race, ethnicity, and socioeconomic status, incorporating multiple learning modalities and domains into reforms are integral (Adebule & Aborisade, 2014; Belbase, 2013).

Most schools have been keenly aware of the existence of the achievement gap in mathematics to some degree since the implementation of the NCLB (2002) mandated that certain types of data be measured to maintain accountability. Despite almost two decades of data-driven reforms, the issues surrounding the achievement gap are pervasive as ever

(Crouzevialle & Darnon, 2019; Demie, 2015; Howard, 2019; Milner IV, 2017). If the way to economic and social stability exists through post-secondary education, underrepresented groups of students have been consistently left behind their peers (Kaupp, 2012). Further, the existence of such a gap influences how minoritized students (those of non-White background) experience school and has negative implications on graduation rates, college attendance, and college completion (Leach & Williams, 2008). An added impact when underrepresented groups of students fail to graduate from post-secondary education is the incurrence of high levels of student loans. For example, Luna-Torres et al. (2018) sought to discern if racially or ethnically diverse students were more likely to incur high levels of debt while taking collegiate coursework. In a quasi-experimental study, the researchers analyzed the enrollment, loan amount, and success of 5,871 students enrolled in a two-year community college. Of these students, 60% of Black students, 19% of Hispanic students, and 12% of White students were loan recipients. Further, of the students who took out a loan, 57% did not earn a credential, and while there was no significance when analyzing the relationship between ethnicity and cumulative debt, Black and Latinx students were less likely to earn a credential or transfer to a four-year institution (Luna-Torres et al., 2018). Such results not only create socioeconomic stagnancy for the current generation of underrepresented groups of students, but according to Kaupp (2012), these outcomes also have direct implications for their children, who struggle to break the cyclical nature of poverty.

Blaming poverty alone does nothing except mislead those who are seeking to find viable solutions to the problems that create the achievement gap. Communities that are not highly involved in the education of their children are much more likely to see well-meaning reforms fail; put simply, the community must buy into the vision of the school as a whole

(Ferguson et al., 2010). If leaders within the community are not willing to step forward to support the school and do not have a stake in educating children equitably, then the school itself will be unable to combat the external factors that negatively impact students' lives, such as crime, poverty, social mobility, and social disorganization (Bryan, 2005; Lee & Madyun, 2009; Rothstein, 2015). In areas that exhibit these attributes, a common result is the school to prison pipeline, which further inhibits underserved groups by contributing to limited employment opportunities (Alexander, 2020; Allen & White-Smith, 2014; Owens, 2017; Wald & Losen, 2003).

The close focus on the achievement gap in mathematics has good intentions, but many argue that it overshadows ways that schools use school discipline, special education, and juvenile justice to constrain student achievement data (Annamma et al., 2014). Punitive measures for minoritized students create an environment in which underrepresented groups are unwelcome and additional barriers are put in place to experience success. For example, the Black-White suspension gap contributes to the racial gaps in academic achievement due to the utilization of school exclusion as a discipline practice (Skiba et al., 2014; Winn & Behizadeh, 2011). Williams (2011) addresses another of these barriers within schools, as mathematics courses act as a foundation for the knowledge later, creating a situation where courses like Algebra are gatekeepers to future success in any mathematical or scientific field (Douglas & Attewell, 2017). To address the challenges caused by gatekeeping courses, Moses et al. (1989) created the Algebra Project in 1982, which operated under the assumption that all students can learn Algebra. Their work established a series of components that created a curriculum to meet students where their current abilities were and linked personalized experiences with student learning strategies. In essence, these components seek to combat the implicit biases that have existed within schools and other social institutions (Silva et al., 1990). Although some success was experienced, ultimately exclusionary discipline practices and gatekeeping courses continue to result in later disparities in employment opportunities for underrepresented groups of students.

As global employment is becoming more competitive, those who are more likely to have dropped out or have become incarcerated are less able to maintain socioeconomic stability (Rosenberg et al., 2012). The incongruities that are present in education are applicable to life outside the four walls of a classroom, as they are prevalent in property ownership, public accommodation, and voting rights, as multiple studies have indicated (Bacharach et al., 2003; Finkelman, 2009; Rauh, 2017). For these reasons, it is crucial to ensure that students have opportunities to achieve success in mathematics. Not only do the skills required within the curriculum create opportunities for future success, but remediation within mathematics courses acts as a gatekeeper for success at the secondary and post-secondary levels (Wang et al., 2017). The existing reality is many underrepresented groups of students must take these remedial courses, which adds another barrier to be successful (Crisp et al., 2015). In order to fully understand how students are impacted both in the short and long term, light must be shed on the cause of the problem.

Historically, teaching and assessment in secondary education have primarily focused on the cognitive skills of knowledge and understanding. After the analysis of the quantitative results of standardized testing, several studies caution the overabundance of cognitive reforms and determined that affective outcomes like values, attitudes, and behaviors may be equally important to provide a holistic and personalized education for all students (Deunk et al., 2018; Shephard, 2008; Hall, 2011). Specifically, Deunk et al. conducted a meta-analysis on cognitive reforms as they relate to differentiation in the classroom, and the researchers concluded that a broader educational context was needed. One of the suggestions was an incorporation of students' affective strengths to support the individual needs of each student. The current lack of focus on students' affective domain ultimately contributes to a negative emotional reaction in mathematics education. To address this perception, Ignacio et al. (2016) posit there needs to be a change in the image of mathematics instruction and an improvement in the relationship between teachers and pupils.

Although a consistent focus on cognitive reforms may be a factor in the current achievement gap in mathematics, it is not the only cause. Research dictates there are several factors that have contributed to schools' inability to narrow the achievement gap. Although many districts have implemented reforms to address such an issue, multiple studies have determined that schools that do not have strong leadership, high-quality teaching and learning, an inclusive curriculum, effective use of data, one-to-one support, and do not deploy the best teachers to teach intervention groups generally experience less success in closing the achievement gap in mathematics (Demie, 2015; Dittmann & Stephens, 2017; Wu et al., 2021). Traditional methods of instruction have not been able to combine enough of these characteristics to enact lasting change, and students' engagement levels in mathematics have declined, especially among minoritized groups of students (Skilling et al., 2020). Some researchers have claimed the cause stems from the lack of high-quality educators within a geographic region (Goldhaber et al., 2015). Others posit that the issue is not one of race or ethnicity; instead, poverty is the major culprit (Baker et al., 2016; Evans, 2007). Still more argue that low expectations and cultural differences create educational inequity that is further strengthened in the placement of students in remedial classes during later years (Kotok, 2017). These characteristics all likely have an influence on the achievement gap in mathematics and drastic implications on how teacher education and development must shift to provide culturally responsive discourse within the classroom (Milner IV, 2017). To avoid these impacts of the achievement gap, school districts need to be more creative in the allocation of their resources.

Changing the Instructional Model

In a typical classroom, students have differing levels of understanding based on their interests, familial background, district mobility, and natural ability (Loughran, 2013). If given enough time, an educator can test to see how much a student knows, analyze the results, create a personalized learning plan, and develop a method through which a student is held accountable for content performance. The classroom operates with limited resources, however, and teachers cannot do all these things simultaneously. Herein lies the promise of educational technology, as it offers the potential to differentiate on a personal basis and create a system in which the teacher's role is redefined as a facilitator of information, thus increasing overall achievement and reducing the gap for underserved populations. In short, technological advances have the potential to weave together each of the domains (affective, cognitive, and psychomotor) to produce learning (Bloom, 1956; Kapp, 2012). In mathematics, traditional instruction is relegated to impersonal interactions between students and teachers, with direct instruction being the primary method of delivery due to its efficiency. To investigate an alternative style of instruction that supported the affective domain, Boyle et al. (2007) studied the effects of fieldwork in various courses rooted in science, technology, engineering, and mathematics. The researchers posited that increased support of students' affective domain would lead to the incorporation of more effective approaches to learning. In a pre/post Likert survey presented to 300 participants, the percentage of students who felt negative emotions toward the coursework fell from 39% prior to the course beginning to 13% after the course ended (Boyle et al., 2007). Specifically, students communicated they felt more connected to individuals around them and had a better understanding of their content area's application in the real world, as both characteristics were significant at the .05 alpha level. The research from Boyle et al. (2007) indicates if educational interactions become more personalized, there is a significant impact on the affective domain, as how student's feel about the content they are learning is crucial to their levels of retention. In general, instruction that can provide a connection to each student creates a more positive interaction. The core of every educational organization's mission statement includes some reference to academic success; to reach high levels of achievement for all students, however, they must also exhibit competence in emotional intelligence (Lynch et al., 2009). Due to the limitations of resources, asking educators to balance the personalization of instruction while also developing their students' emotional well-being is nearly an impossible task. If carving out more time within a day is not a possibility, perhaps a better approach would be to focus on incorporating technology successfully, which helps the system become more efficient.

Educational technology can facilitate a personalized learning environment, which creates the potential to shift the role of the teacher to support students' cognitive and affective domains, and empirical research has shown that e-learning can improve learning interest, attitude, and local cultural identity (Hwang & Chang, 2016). However, a traditional criticism is one of turnover; by the time a school district commits to a curricular design, the technology changes or becomes obsolete (Selwyn, 2015). As a result, school districts have a difficult time maintaining a particular technology or software. Additionally, pressures of accountability by public policies have only redoubled the focus on the cognitive domain and created a negative connotation for any program that seeks to focus on the affective domain, as it is often harder to measure by a standardized test (Deming & Figlio, 2016). Traditionally, cognitive tutoring programs were designed by companies seeking to turn a profit, so they were tailored to learning standards that addressed only the cognitive domain (Sottilatre et al., 2016). Unlike previous endeavors, newer adaptive learning programs have taken a different approach and offer an opportunity to truly meet the diverse needs of students while supporting all learning domains. One of these programs, the Summit Learning Platform (SLP), creates a more conducive, personalized environment for the student, and the study examined whether the utilization of the SLP can generate a positive association when measuring mathematics achievement (Summit Public Schools, 2017).

The SLP was chosen because it offers the most promise to meet the holistic needs of students. For example, a hallmark of the program includes finding the exact location of students' levels of understanding over a curricular topic, as developing cognition is hinged on skills that can be accessed within each student's zone of proximal development (Bruner, 1960; Vygotsky, 1978; Wood et al., 1976). This approach speaks to the cognitive domain that many other adaptive learning models support. In theory, such programs present the ability to not only challenge high achieving students, but also provide the remediation that some underrepresented groups of students may need to catch up to their same-aged peers. Equally important to the implementation of the SLP is a focus on the affective domain, given its influence on the quality of school-level learning and the emotional reactions students experience while learning (Ignacio et al., 2016). Although content knowledge is one of the building blocks of the SLP, developing habits of success for students to support positive behaviors, mindsets, and dispositions are significant to the effective mathematics classroom (Stafford-Brizard, 2016). A final piece of the SLP involves creating a sense of purpose through meaningful experiences to develop self-knowledge, values, relationships, and a credible plan for the future (Duckworth & Duckworth, 2016; Rath et al., 2010). Rather than addressing the disparity in education solely through cognitive reform, the SLP attempts to support students by also utilizing personalized learning to help students seek growth in the affective domain.

Purpose and Research Questions for the Study

The purpose of this study was to determine if Summit Learning Platform (SLP), a type of Intelligent Tutoring System, positively affected mathematics achievement, as measured by pre-post and between-groups measures. Additionally, the study sought to determine if the SLP can narrow the inequities that currently exist for underrepresented groups of students and FRLQ students in a suburban public school outside a large Midwestern city when compared to similar students in a traditional education setting. In this study, the underrepresented groups consisted of African American, Latinx, Multi-Ethnic, and FRLQ students due to the available sample sizes. The study served two purposes for contributing to the existing body of research. First, it can help professionals in the field of education decide how a cognitive tutoring system may create a personalized learning environment for all students at the high school level. Second, there is an existing gap of independent research on the SLP, which may provide additional credibility to its wide-scale application. For this study, data were collected and analyzed to answer the following research questions:

1. Is there a significant difference in NWEA-MAP mathematics scores when comparing student pretest and posttest results among students using the SLP?
2. How do mean posttest mathematics scores differ among students by race/ethnicity and income status when using the SLP, as measured on the NWEA-MAP? Specifically, do scores differ among Black, Latinx, Multi-Ethnic and White students? Are scores different between FRLQ students and non-FRLQ students?
3. Is there a significant difference in ACT mathematics scores when comparing 11th grade students who received traditional instruction and students who receive instruction using the SLP?
4. Is there a significant difference in pre-ACT mathematics scores when comparing 10th grade students who received traditional instruction and students who receive instruction using the SLP?
5. How do mean posttest mathematics scores differ among students by race/ethnicity and income status when using the SLP, as measured on the pre-ACT and ACT? Specifically, do scores differ between Black, Latinx, Multi-Ethnic and White students? Are scores different between FRLQ students and non-FRLQ students?

Theoretical Framework

Although scientists have studied cognition to a great degree throughout the past century, research on the overlap of cognitive science and technology is relatively new due to developments that have occurred in only the last few decades (Falmagne et al., 2006). Of the plethora of Intelligent Tutoring Systems (ITS), adaptive mathematics software programs like the SLP primarily operate utilizing Knowledge Space Theory (KST) and Adaptive Control of

Thought-Rational (ACT-R). These two theories intertwine to establish the theoretical framework of the research study.

Doignon and Falmagne (1985) developed the concept of KST to utilize artificial intelligence to uncover a close approximation of the exact state of knowledge of a student. Within KST, a basic unit of knowledge is defined as an item, which can be a single question, a set of questions, or even a performance task (Villano, 1992). The SLP primarily gauges student knowledge by asking open-ended constructed response questions. Through a mixture of cognitive tutoring and teacher-supported instruction, additional levels of understanding are gained (Summit Public Schools, 2017). Further, to develop students' content knowledge, instruction is provided in students' zone of proximal development (Vygotsky, 1978). To use artificial intelligence, Doignon and Falmagne (1985) operationally define the zone of proximal development as the domain set of student knowledge. Understanding how the process works is equally important for both researchers and educators who seek to apply adaptive tutoring systems to the field of education.

The result of the initial adaptive assessment creates two shortlists of problems: What the student can do and what the student is ready to learn (Falmagne et al., 2006). Such an application of KST is crucial because the accuracy of the student placement ensures the most efficient and effective methods of instruction. Initially, individuals believed that a true student-knowledge state could not be determined by artificial intelligence, but the work of Doignon (1994) demonstrated that "a finite knowledge space can be generated from a skill assessment that is minimal and unique up to an isomorphism" (p. 117). This result expanded upon the work of Falmagne (1989), which posited that adaptive testing assessments are more effective when they are deterministic, rather than probabilistic, as randomness should not be present within the concept of KST. The ultimate purpose of KST, regardless of the ITS that utilizes an adaptive assessment, is to provide exact, guided instruction for students. Additionally, teachers are better able to provide personalized instruction for students by allowing them to apply the learning pathways demonstrated by the students themselves (Taagepera & Noori, 2007; Taagepera et al., 1997).

Failure to mention how ACT-R has shaped the way adaptive tutoring systems are created would be incongruous to the research. Much like KST, ACT-R seeks to assess current knowledge and provide individual instruction (Roll et al., 2011). Different from KST, however, ACT-R analyzes how the brain is organized in such a way that allows individuals to process modules to produce cognition (Anderson, 1996). In terms of the SLP, this references a question or series of questions that target higher-level cognition. Such a perspective is crucial to the success of an ITS because, to gauge student understanding, users must be able to interact successfully with the program. In other words, even if an adaptive assessment is designed perfectly, the interaction between user and software may cause issues in determining the exact knowledge state (Anderson, 1996). This is perhaps where the greatest strides have been made, as the seminal research and subsequent applications of ACT-R modeled higher-level cognition, but by the standards of human-computer interaction (HCI), it was deemed to be failing (Anderson, 1993; Anderson et al., 1997). As technology has improved, the ability of artificial intelligence to interact with a student and work toward determining their current mathematical understanding has more closely modeled that of a teacher (Hunter, 2018). Although ITS models are far from perfect, and gaming the system does result in disengagement from the topic and decreased learning, it is important to remain focused on the overall goal: Personalized learning does have the capacity to transform the way learners consume information (Baker et al., 2008).

In the traditional classroom setting, being able to differentiate on a wide scale is nearly impossible, as each student has unique needs, culturally specific psychosocial stressors, and a separate knowledge state from all other students (Patel et al., 2016). Personalized learning through software that utilizes the theoretical basis of both KST and ACT-R allows teachers to meet each student on their level, target instruction to the exact area of need, and support characteristics like resiliency and self-regulation that help students achieve success (Evans, 2007). The cognitive model reinforces these goals, as it can predict what students can and cannot do and help them achieve curricular goals (Ritter et al., 2007). Further, Davidovic et al. (2003) studied the results of 117 high school students who used a structural example-based adaptive tutoring system (SEATS) to determine if a computer model could be an effective delivery model for students. The study placed students into four randomized groups, and the results indicated that although all groups acquired knowledge, those who utilized the SEATS model experience the largest knowledge gain in the shortest amount of time as measured by both a pre-test/post-test model in addition to a survey. These results indicated that the utilization of ITS models like SEATS can lead to increased engagement, motivation, and learning within a safe, non-competitive environment (Davidovic et al., 2003). By raising engagement and providing an increased level of individualization, students are empowered, and teachers can facilitate various methods to control the boundaries of adaptation, which may aid in the process of narrowing the achievement gap in mathematics (Turker et al., 2016).

Moving away from the traditional approach of mathematics education to a personalized environment can be difficult to manage for organizational leaders. This reality is especially true as schools attempt to address the diverse needs of underrepresented groups of students. Further, by failing to approach instructional change through an aligned, purposeful system, buildings cannot sustain any transformation. Instead, effective leaders support their teachers by involving them in the decision-making process, which is a characteristic of transformational leadership (Usdin, 2014). To narrow the achievement gap, leaders must be able to alter the way teachers see the structure of the classroom and help to create a sense of purpose within teachers by evoking them to think critically. Simultaneously, teachers must be supported emotionally, and these factors are effective ways to stimulate the positive student outcomes desired by so many districts across the nation (Boberg & Bourgeois, 2016). For this reason, the implementation of the SLP is best analyzed through the lens of transformational leadership. Although a program may utilize KST to determine the exact state of student knowledge and apply ACT-R to interact effectively with students, the incorporation of technological tools can only be successful if a leader facilitates the implementation by providing opportunities for training, development, and reflection. These theories are expanded upon and further examined in the literature review.

Measurement Tools

Three main assessment tools were utilized in this study. First, the pre-ACT is a norm-referenced assessment developed by the ACT to provide an early indication of educational progress, areas for improvement, and quick reporting to the student (ACT, 2018). Many districts give the pre-ACT to 10th grade students to provide a benchmark before they take the ACT the following year. The second assessment analyzed was the ACT, which is primarily given to 11th grade students throughout the nation at various dates throughout the year. The ACT both provides students with a guide of college readiness and is also a high-stakes test, as universities partially base acceptance and financial decisions on ACT score (Goodman, 2016). Finally, I utilized the Northwest Evaluation Association Measures of Academic Progress (NWEA-MAP) to analyze student growth throughout the year. Schools give this norm-referenced assessment three times a year to gauge individual student growth and instructional gains within a school year (NWEA, 2018). The school district participating in this study administers the pre-ACT to all 10th grade students at all three high schools, the ACT to all 11th grade students at all three high schools, and the NWEA-MAP to all mathematics students at one of the three high schools.

Significance of the Study

Compared to some of the seminal studies of human cognition, the research that has paired software development with cognitive science is much more limited (Roll et al., 2011). Typically, researchers in the field have not focused on gains in achievement by analyzing quantitative studies but rather on the theory behind the ITS software (Aleven et al., 2006). Though there are a vast number of software programs that utilize adaptive learning, ALEKS is the most popular and is employed across the nation, primarily in secondary and post-secondary institutions (ALEKS Corporation, 2019). The SLP follows in the footsteps of the ITS models that came before it, simulating the responses of a human tutor to provide hints, giving immediate feedback, and helping students proceed at their own pace through assessments that utilize artificial intelligence to generate students' unique knowledge spaces (Summit Public Schools, 2017). Table 1.1 provides a brief look at some of the more prevalent adaptive software models, as well as a summary of their perceived strengths and weaknesses.

Table 1.1

Summary of Intelligent Tutoring System (ITS) Models

ITS Model	Description	Perceived Strengths/Weaknesses
Assessment of Learning in Knowledge Space (ALEKS)	A web-based, artificially intelligent assessment and learning system that uses adaptive, non-multiple-choice questions to determine student knowledge (McGraw-Hill Education, 2018).	ALEKS does provide an immense amount of support, and the mastery requirement has demonstrated increased student achievement. The cost is prohibitive, as each subscription costs $19.99 per month
Carnegie Learning's Cognitive Tutor	Software that monitors that student's knowledge on a moment-by-moment basis and tailors coursework based on continual assessments (Carnegie Learning, 2018).	Although it does utilize computer-adaptive instruction, the hint feature allows students to "game" the system. Also, the cost for a district can be prohibitive.
Edmentum	Formerly PLATO Learning, Edmentum offers a variety of K-12 mathematics products and tools to engage and monitor progress toward grade-level standards (edmentum, 2018).	Edmentum has a great number of tools, from games to assessments for students. Most of the games and technology are geared toward younger ages, and the cost may be prohibitive.
Relational Adaptive Tutoring Hypertext (RATH)	A landmark ITS model, RATH is a prototype that combined the structure of hypertext with the theory of knowledge spaces. By determining the knowledge state of a student, RATH presents only relevant material (Hockemeyer et al., 1997).	This is not a current ITS model, but many of the current products on the market utilized the revolutionary research done in the creation of RATH and the subsequent research that has stemmed from its development.
Summit Learning Platform (SLP)	A free, online tool that helps students track progress, learn content, and reflect. Teachers customize instruction and provide personalized learning (Summit Public Schools, 2017).	It requires teachers to facilitate instruction of the program, which is counter-intuitive of many online learning platforms. Basic use is free for school districts.

As of this writing, many school districts are turning in the direction of computer software programs to help provide personalized learning experiences for the children under their purview. As a result, there have been increased incentives for companies to sell their products to public schools, despite the availability of research-based pilot programs (Rani et al., 2015). Further, research is often conducted by the company attempting to distribute its product, which has ethical concerns (Hubalovsky et al., 2019). Many school districts are changing from the traditional style of mathematics instruction to one that is much more personalized without objective research to support such a pedagogical shift (Bergman & Chan, 2019). Thus, there is a crucial need to investigate the effectiveness of adaptive learning software by an individual who has no ties to a company and is not employed by an organization that creates intelligent tutoring software for entrepreneurial gain (Rashid, 2019). Further, there has been little research done that compares students who are utilizing the SLP to those who undergo the traditional models of instruction within the same district. Such a quasi-experimental quantitative approach may help educators, administrators, and other stakeholders make informed decisions that could benefit their school district.

Educational reform often comes with its unique jargon. For the reader, and even professionals in the field, this such language can be both confusing and difficult to manage. To ensure there is consistency, Table 1.2 lists key terms, their corresponding acronym, and a brief definition. These acronyms are utilized consistently in the literature review as well as in the methodology and results sections. Additionally, these are included in scholarly articles that address any form of a cognitive tutor.

Table 1.2

Definition of Key Terms

Term	Acronym	Definition
Adaptive Control of Thought- Rational	ACT-R	A theory of cognition that focuses on memory processes to explain human cognition and understand how people organize knowledge and produce behavior.
Assistive Technology	AT	Equipment (including but not limited to technological) that increases or maintains the functional capabilities of a child.
Cognitive Tutor	CT	A type of Intelligent Tutoring System that utilizes a cognitive model to provide feedback to students.
Cognitive Science	CS	The scientific study of the mind and its processes.
Computer-Assisted Instruction	CAI	An instructional technique where a computer is used to present the material and monitor learning.
Depth of Knowledge	DOK	The comparison of the complexity of thought required of students within standards and assessments.
Intelligent Tutoring Systems	ITS	A computer system that provides immediate or customized instruction or feedback to learners without requiring human interventions.
Knowledge Space Theory	KST	A psychological framework for the adaptive assessment and teaching of knowledge.

Limitations and Ethical Consideration

There are several limitations of the study which must be addressed. First, the experimental group only contains students in grades nine through eleven, so the results of the study can only be generalized for the sample population of students. Currently, other measures that may gauge student success, like high school graduation rate, remediation in college, or college graduation rate, were not considered in the scope of the study. A second limitation is the Intelligent Tutoring System itself, as the results of the study are limited to the SLP and cannot be transferred to other ITS models utilized throughout the nation. Additionally, the findings of this study cannot be used to make claims about the effectiveness of blending learning models, as more schools attempt to differentiate through the incorporation of technology into the classroom environment. Further, because various statistical tests were used to analyze the data in the study, there is potential for researcher error within data analysis. By utilizing SPSS Statistical Software and its subsequent results, this possible error was mitigated. A final limitation is the data collection process. Due to the Novel Coronavirus (COVID-19) Pandemic, data were not available for the 2019-2020 school year. Moreover, students who elected to be virtual students were reclassified in the district's student information system, convoluting the process to organize data appropriately by control or treatment group. These factors, combined with the fact that the treatment group has added a single grade level since 2017-2018, means only data gathered from students in grades nine through eleven were able to be used.

In addition to the limitations of this study, student data were used from the high school and school district that employs me, so other ethical considerations need to be addressed. First and foremost, all measures were taken to ensure student privacy via the Family Educational Rights and Privacy Act (FERPA). Further, all markers of individual students were removed so I could only classify students by demographic fields, such as gender, race/ethnicity, and income status. These steps, conducted by central office administration, make it impossible to discern students simply by their data. Also, the tests being utilized have a great deal of research demonstrating both validity and reliability in their assessments (ACT, 2018; NWEA, 2018). Although the tests are both reliable and valid, there is still an ethical concern that there is geographical bias in testing or that test scores could be impacted by cultural differences (Epstein, 2019; Gonzalez Canche, 2019). Finally, before collecting any student data, I completed the requisite modules in the Collaborative Institutional Training Initiative (CITI) program and received Institutional Review Board (IRB) approval for the study. Further, a respect for persons and beneficence were demonstrated, and procedures were observed that promote and protect justice, as defined by the Belmont Report (1978). The steps taken helped to mitigate the ethical considerations that may be a topic of concern by others in the field.

Organization of Chapters

Chapter 2 reviews the relevant literature to provide a rich overview of contemporary trends in mathematics education. This gives a better understanding of how mathematics pedagogy has shifted throughout the past century, which is critical to determining how to overcome the existing barriers to reform mathematics education. Historical institutional structures and their seemingly permeance in contemporary schools contribute to gaps in achievement and opportunity. Central to these reform efforts is combating the existing ideology that the cognitive domain should take precedence when dealing with educating students. Laying out the framework to the creation of the Summit Learning Platform, historical successes and failures of other ITS models are described. Within this section is a more detailed analysis of KST and ACT-R, where additional details help explain the importance of estimating what a student knows and why software must interact successfully to supplement traditional classroom instruction. The concluding section of leading the change highlights the styles of leadership that educational professionals must embody to successfully institutionalize personalized learning models within a school district. Chapter 3 describes the research design and the appropriation of various statistical methods to test each of the hypotheses. In Chapter 4, the results of the study and analysis of the data provide the reader with a detailed overview of the quantitative basis behind the research. Finally, Chapter 5 includes discussions of findings, provides conclusions and implications, and closes with the relevant limitations and recommendations for future research.

CHAPTER 2

REVIEW OF LITERATURE

This chapter is organized to provide a thorough review of the literature relevant to the field of study and add to the significance of the research while concurrently analyzing the relevant research in the field. The chapter begins with an overview of contemporary trends in mathematics education and describes the skills gap, movement toward standardization and accountability among schools, achievement gap, and mathematics achievement. This section is followed by instructional changes to mathematics over time with blended learning as a pedagogical practice. Next, learning domains of cognitive, affective, and psychomotor domains are discussed at length, with a critical lens regarding the focus of nationwide reforms as they relate to the domains of learning. Later, the chapter includes a discussion of the theoretical framework of personalized learning, which includes the interaction of Knowledge Space Theory (KST) and Adaptive Control of Thought (ACT-R) and how these combines to produce an effective Intelligent Tutoring System (ITS) model. Finally, a comprehensive analysis of transformational leadership and instructional leadership discerns how to effectively implement educational technology to contribute to the narrowing of the achievement gap.

Contemporary Mathematics Trends in American Public Education

The transition to an implementation of educational technology has been an arduous journey, and to better understand some of the obstacles that currently exist, trends in mathematical education must be explored. First, the historical context of public schools is discussed; past institutional structures and their seemingly permeance in contemporary schools contribute to gaps in achievement and opportunity. Next, the skills gap and global competition is presented to include issues related to standardized testing and accountability, achievement gap, and mathematics achievement.

Historical Context of Public Schools

The common school movement, stimulated by Horace Mann from 1820 to 1850, was viewed as a way to form the character of the nation through an emphasis on a "theory of the appropriate character of a democratic economy and the role of education in sustaining that economy" (Persky, 2015, p. 254). Before the movement, schools reflected class, religion, ethnicity, race, gender, and regional differences. The Protestants operated their own elementary school systems and Germans had maintained schools for generations. Further, White Southerners believed that the government had no right to intervene in the education of children or the larger social order (Anderson, 1988). Hence, schools flourished the most in the Northeastern colonies; in the South, there were limited interest to educate the laboring class (Spring, 2017). While free schools in the city were designed for the poor, the upper class tolerated the idea of pauper education as a charity for poor White children but was against state supported education. The Lancastrian system, developed for pauper boys and the Sunday school, was one day of the week to inculcate poor children with Protestant civilization (Nasaw, 1979). Generally, Whites who could afford private schools preferred to send their children to these institutions or hire private tutors.

Nineteenth century paupers who were White and given remedial attention were believed to have the capacity to be cured of the character defects passed along by their poor parents (Nasaw, 1979). Blacks and Indians were also poor, but because their poverty was derived from different characteristics regarding notions of civilization (Adams, 1995), the quality of their institutional rehabilitation was different. "And since, by law of historical progress and the doctrine of social evolution civilized ways were destined to triumph over savagism, Indians would ultimately confront a fateful choice: civilization or extinction" (Adams, 1995, p. 6). The Negro, characterized as violent, low intelligence, and immoral, stood at the bottom of civilization (Garo, 2018; McLaren, 1995; Pilgrim, 2012; Spruill, 2016; Woodson, 1990).

Most Blacks were enslaved on plantations and kept in their places by laws, customs, and social practices (Corder & Quisenberry, 1987; Mintz & Stauffer, 2007). Corder and Quisenberry (1987) reported that by 1840, only 15 schools educated enslaved Blacks in the South. While the Sabbath school was more formal, the other type of education available to slaves was the clandestine or midnight school. Education was one of the foremost aspirations of many slaves; often assisted by Whites, they were willing to risk the wrath of their owners and lives to become educated. Although the Northern states did not have explicit laws, social practices kept Blacks in segregated institutions; several states, Ohio, Illinois, and Oregon, established laws that kept free Blacks from entering the states (Nasaw, 1979).

Indian children were institutionalized, taken away from their families to ensure that they would not be influenced by the tribal home (Takaki, 1993). From the initial campaign to "Kill the Indian, Save the Man," (Bess, 2000, p. 8) which described Pratt's famous slogan for educating Native Americans, the first boarding school was established at Carlisle, Pennsylvania in 1879. Colmant (2000) described the boarding school as designed to assimilate students into the European-American culture – a form of civilization. By forcibly removing children from their environments, the experience for students was harsh to say the least, as they had to endure substandard educational practices and conditions (Dlugokinski & Kramer, 1974; Running Bear et al., 2018; Zephier-Olson & Dombrowski, 2020).

The United States and Mexico signed the 1848 Treaty of Guadalupe Hidalgo that ended the Mexican American War, and the US acquired a significant portion of Mexico's land. The treaty "signaled the beginning of decades of persistent, pervasive prejudice and discrimination against people of Mexican origin who reside in the United States'' (San Miguel & Valencia, 1998, p. 353). For the most part, Mexican children were segregated in "Mexican schools" and experienced Jim Crow discrimination like that experienced by Blacks (De León & Calvert, 2013).

The common school was achieved due through the mythological development of a nation that entailed "a seedbed of republican virtues and democratic freedoms, a promulgator of individual opportunity and national prosperity, and national prosperity, and an instrument for social progress and harmony" (Adams, 1995, p. 18). Horace Mann, the major proponent of the common school, sought to build a system that would teach the basic principles of a republican form of government needed for individuals to acquire the beliefs and behaviors of good character. Tyack and Cuban (1995) assert that "from the Revolution onward, educational theorists have self-consciously used schooling to construct the citizens of that new order" (p. 2). The citizens of the new nation were Protestant and White and other racial/ethnic groups were viewed as not fit to be citizens.

Based on what he had learned from Prussia's application of "common schools," Mann grouped students by age rather than aptitude and implemented the lecture model of European universities (Mann & Fowle, 1839). This structure was created to facilitate the lecture model of curriculum delivery, which was able to maximize efficiency on multiple fronts (Kaur, 2011). The utility of the lecture model was evident, as it could be incorporated in nearly any physical space with a maximum number of students. Moreover, it reinforced conformity to the White culture and forced assimilation (Salomone, 1996). De Witte and Lopez-Torres (2017) researched the connection between the economics and efficiency of education and determined that when schools are organized in such a way where the financial implications of education are placed at a higher priority than student learning, achievement levels decrease, as measured by the National Center for Education Statistics (NCES). Further, there is an imbalance to the focus on all student learning domains, as reform efforts typically are limited solely to the cognitive domain, which seemingly addresses the standards of learning measured by standardized testing. Another consequence of common schools was its rigidity, as the lecture model did not allow for differentiation and students' individual needs were not considered. The child was viewed as a product of an educational business, and if a student was unable to learn a particular subject, then it was the teacher's duty to keep moving forward (Kaestle, 1983). The rigid structure of common schools, combined with a constructed environment with limited resources, had a damaging impact on minoritized groups.

The expansion of schooling in the new nation, through common schools, was aimed at establishing a dominant culture that became a method for Americanizing immigrants and other cultural groups (Caruthers, 2007). The common school movement served as a buttress for these ideas and produced schools that have remained stable in purpose, core operations, structure, and curriculum (Darling-Hammond 1997; Spring 1997, 2017; Tyack & Cuban 1995; Tyack & Hansot 1982). As public schools grew across the nation, this goal promoted tensions among Indigenous People, African Americans, and other marginalized groups regarding education. A major way of promoting the goals of the common school was through teacher training programs that promoted ideas about efficiency, resembling expectations of industry (De Witte & Lopez-Torres, 2017; Kaur, 2011; Taylor, 1947).

Schools soon expanded to emulate an industrial society using the principles of Taylorism from Taylor's (1947) Principles of Scientific Management, first published in 1911. The primer of managerial techniques was applied in industry and other American institutions to promote efficiency and productivity. The argument was schools could improve by using the "principles of social functionalism, efficiency and productivity, individualism, and expertism" (Goodman, 1995, p. 23) to change curricula and institute new management systems that reflected corporate values, dominant social practices, and individualistic goals. School educators took pride in emulating the practices of business, and the dominant social practices became barriers for non-White students, further supporting historical and institutional racism.

The widespread application of teacher training programs and a universal public education across all states led to the development of the factory model school (Darling-Hammond, 2000). Such an industrial approach to education was the perfect fit for the beginning of the twentieth century due to the plethora of manufacturing jobs that did not require advanced training and higher-order skills. Since the early 1900s, however, the job market has changed drastically. With advancements in technology, robotics, and automation on a global scale, there is no longer a need for a high volume of unskilled workers. To remain competitive, the expectations of what a worker must be able to do have increased exponentially, and a college education is commonly required; however, for some marginalized students, college equal education remains unattainable.

The *Brown vs Board of Education* (1954) decision launched the desegregation era and became a catalyst for change in race relations in the larger society; an assimilationist vision during the 1950s and 1960 that ran its course with the decease of desegregation decrees (Brown, 2004). Today, many marginalized students remain in segregated settings despite the efforts to desegregate schools. Vasquez Heilig et al. (2019) performed descriptive and inferential analyses of publicly available Common Core of Data (CCD) to study segregation at the local, state, and national levels. Findings suggest Black and Latinx students attend intensely segregated public schools. Yet, the following status of charter schools was significant to their examination:

> A majority of states have at least half of their Black students and a third of states' Latinx charter students are enrolled in intensely segregated schools. At the city level, we find higher percentages of charter students were attending intensely segregated schools than urban students enrolled in public schools. (p.12)

In the face of dynamic societal changes, the factory model of education has remained relatively unchanged since its inception over 150 years ago (Zoch, 2004); compounded by segregated schools for Black and Latinx students. Lewis, et al. (2015) put forth a convincing argument for the reality of integrating schools within an environment where even with good intentions, "racial hierarchies are perpetuated" (p. 34) and many scholars view segregated schools as indicators of inequalities.

This persistent structure of schools has resulted in a skills gap among US students. Although it may be rooted in a variety of causes, the current skills gap has led to a heightened sense of global competitiveness, often quantified through the utilization of standardized testing (Coburn et al., 2016). To improve its rankings among peers, the United

States has developed policies at the local and federal level to increase accountability. Hence, the most recent authorization of Every Student Succeeds Act (ESSA) (2015) with an emphasis on college preparedness for all students. Bauman et al. (2019) investigated the results of the shift in focus and its impact on marginalized students. The researchers used semi-structured interviews with a variety of students of racial/ethnic backgrounds to determine the circumstances under which these students experienced success in college. Ultimately, they found that Black students were half as likely as White students to attain a four-year degree and Latinx students were a third as likely as White students to attain a four-year degree (Bauman et al., 2019). These data, and their consequences, are presented in subsequent sections.

The Skills Gap and Global Competitiveness

Successful performance in a job is inextricably linked to mathematics proficiency. In entry-level jobs and occupations requiring formal educational attainment, computerization and information-processing demands are making numeracy skills a prerequisite (Heisig & Solga, 2015; Steedle et al., 2020). Further, countries that have a higher percentage of workers with numeracy and literacy skills have a positive association with economic performance, growth, and innovation (Heisig & Solga, 2015; Toner, 2011). The next generation of workers need to be prepared for this shift, so many high schools and community colleges across the nation have begun to incorporate job-related skills into their curriculum. According to Andrews and Aydin (2020), the best approach to incorporate such changes is to further develop teacher training programs. In a mixed-methods study involving 20 teachers and multiple institutions, training programs that helped students understand roles in their communities raised motivation and self-efficacy levels, as measured by survey data. The researchers determined that educational technology that could interact with technology the students already used was an effective way to integrate some of these changes into the curriculum as it currently exists. Critics argue that such an investment has an immense challenge, as technology changes so quickly that many skills crucial in the labor market today become obsolete within a generation (Dotong et al., 2016; Martz et al., 2017). Despite the increased focus, employers have expressed dissatisfaction with workers' lack of proficiency in problem-solving and mathematics skills, which permeate every quality of a successful worker (Martz et al., 2017).

The lack of certain skills has also been highlighted in recent comparisons to other countries. In 2016, the Organization for Economic Cooperation and Development (OECD) reported that the Program for International Student Assessment (PISA) ranked the United States 40th out of 73 countries in a norm-referenced, comparative assessment of mathematics aptitude. Further, the Trends in International Mathematics and Science Study (TIMSS) indicated that the United States, although improving achievement over the 20-year study, still ranks 10th out of 38 countries, with only 10% of students earning an "advanced" mark on the assessment given (National Center for Educational Statistics [NCES], 2017, para. 2). TIMMS data have been collected from students after fourth and eighth grades since 1995, and the United States have participated in both 1995 and 2015 assessment periods. According to NCES (2017), the assessment has proved to be both reliable and valid for gathering information about student achievement in mathematics and science.

Participation in 2015 was especially beneficial to determine how the United States compared with students from other countries, as data extended to mathematics aptitude in the final year of secondary school across countries and included over 580,000 students in 57 nations around the world. Although there have been positive gains, as demonstrated by community colleges that provide "workforce training programs … [that] require basic and sometimes advanced STEM skills," the gap between the United States and other countries has not closed quickly enough for politicians at the state and federal levels (Lowry, 2017, p. 47). Interested in addressing the skills gap as quickly as possible to provide future generations of workers the training needed to make them globally competitive, lawmakers have sought to increase academic rigor while holding schools more accountable. Federal programs and curricular changes like the Common Core State Standards, which have been adopted in 42 states, attempt to raise student achievement by influencing how teachers teach and how students learn (Coburn et al., 2016; Hodge et al., 2017); which has increased accountability initiatives and standardized testing.

Standardized Testing and Accountability

The biggest piece of legislation that created accountability for school districts was the No Child Left Behind Act of 2002 (NCLB). Although NCLB caused many issues for schools, including setting unattainable goals for the districts, it went a long way in providing standardized procedures for analyzing performance. Oft criticized, the NCLB mandated an adequate yearly performance on a variety of accountability measures and a final goal of 100% proficiency by 2014. The NCLB was far from perfect and contained unreasonable targets, but there was accountability for groups of students who had not traditionally performed well in schools. Teachers must help them meet the school's target, or these students could be given the option to transfer to another school district (NCLB, 2002).

Before NCLB, state tests were not given annually, non-norm referenced, and there were no consequences to repeated poor performance. Consequently, Linn et al. (2002)

reported that underrepresented groups were given fewer resources, inexperienced teachers, and provided less support. Further, states did not disaggregate test scores by ethnicity or race prior to the NCLB, and some states did not even disaggregate data by graduation rate (Linn et al., 2002). Regardless of its impact, NCLB provided schools with the tools they needed to begin to analyze inequity that occurred during their watch. Put simply, the nation began to get explicit evidence of how poorly underrepresented groups of students were doing on standardized tests in comparison with their same-aged peers, based on the National Assessment of Educational Progress (NAEP) (2017). There was a downside to the structure of the NCLB, as arbitrary scores were placed at a higher level of importance than equitable education (Steinberg & Quinn, 2017). Such a reality created a structure in which the NCLB was doomed to fail, as districts were held accountable for test results that were not supported by public policy. As a result, the era of NCLB came to an end and was replaced by a new set of federal policies.

In 2016, the Race to the Top (R2T) initiative and Every Student Succeeds Act (ESSA) refined some of the problematic statutes of the NCLB and refocused on the preparation of all students, regardless of race, ethnicity, or socioeconomic status, requiring schools to offer college and career counseling and advanced placement (AP) courses to all students (ESSA, 2015; United States Department of Education, 2009). R2T sought to financially support schools in the creation of personalized learning models that engaged students in their interests and provided connections to potential career paths while emphasizing interventions that could be implemented within the lowest-performing schools. The ESSA legislation took one step further and put inequity and social injustices in the limelight and encouraged school districts to implement reforms that could help all students be successful, especially those traditionally underserved. Although they are not all-inclusive, these laws laid the groundwork for schools to task administrators to incorporate accountability into their evaluation procedures of teachers. Part of the evaluation progress still includes high-stakes testing. As in previous legislation, mathematics acted as a "gate-keeping" content area, so a high level of accountability continues to be placed on narrowing the achievement gap that exists on standardized assessments. Milner (2012) argues that standardization of policies and practices "suggests that all students live and operate in homogeneous environments with equality and equity of opportunity afforded to them" (p. 694). Further, Ravitch (2016) reversed course of two of her more prominent beliefs in light of the racial bias and institutional racism that results from standardized testing. The first of these beliefs were the adoption of free-market business practices within the educational system, and the second was the use of assessment as the main assessment tool of student learning. Despite her advocacy throughout her career, Ravitch now argued these ideals increase the achievement gap due to implicit biases.

Achievement Gap

Educational agencies at the local, state, and federal levels have made innumerable attempts at reforming public education and poured countless dollars to address a single issue: narrowing the achievement gap. The National Assessment of Educational Progress (NAEP) states that "[a]chievement gaps occur when one group of students (such as students grouped by race/ethnicity, gender) outperforms another group and the difference in average scores for the two groups is statistically significant" (2017, para. 1). Although low achievement in mathematics is an issue for all students, minoritized groups in the United States seem to fail at inequitable rates (NAEP, 2017). As highlighted in chapter 1, mathematics is one of the most scrutinized content areas because it is tied to district funding and scholarships through students' results on standardized tests. However, only 23% of twelfth graders scored at proficient on standardized mathematics tests (NAEP, 2017). Flores (2007) reported that "… 91% of African-American and 87% of Latin[x] students are not proficient in mathematics" (p. 30). More recent studies indicate that this percentage has not changed and have found schools use implicit tracking in mathematics that prevents students from receiving the mathematics content they need to perform well on standardized tests (Bancroft et al., 2017; Kotok, 2017; Malone et al., 2020).

As indicated by NAEP (2017), public policy has attempted to address the achievement gap, but the problem is not a new one. Due to school desegregation, Black students have been scrutinized more than any other group regarding achievement and their status in society (Coleman, 1966; Edmonds, 1982; Irvine, 1990, 2010; Lezotte, 1997; Ladson-Billings, 2006, 2009; Milner, 2013, 2017). A google scholar search using the terms Asian American or Asians in public schools yielded 5,630,000 sources; Hispanic, Latinx and Mexican American terms produced 1,195,400 sources; and African American and Black students in public schools resulted in 6,390,000 sources.

The Equality of Educational Opportunity Study (EEOS), commonly referred to as the "Coleman Study," found there was a significant gap in the achievement scores between White and Black children by first grade. This achievement gap only widened as students progressed through school, with White students demonstrating much higher levels of proficiency than their Black counterparts (Coleman, 1966). The authors of the Coleman Study also analyzed segregation among public schools and observed that almost 80% of all White pupils from first to twelfth grades attended schools that were 90 to 100% White, and more than 65% of all Black pupils in the first to twelfth grades attended schools that were between 90 and 100% Black (1966). Coleman's seminal work created a new wave of research to determine if the assertion that schools were ineffective at breaking the poverty cycle was factual. Edmonds set out to demonstrate that high poverty schools can be effective and studied the characteristics of these schools to determine qualities that could be replicated elsewhere (Johnson, 2016). By analyzing the common characteristics of effective schools, regardless of race or socioeconomic status, several correlates of effective schools were identified: strong instructional leadership, strong instructional focus, high expectations from teachers, frequent monitoring of achievement, and a safe and orderly school (Edmonds, 1982; Lezotte, 1997; Robinson & Lewis, 2017). Although Edmonds and the researchers who followed him presented an alternate view that juxtaposed Coleman's work, the stark reality is data from more recent studies have not shown any marked improvement.

de Brey et al. (2019) using data from the National Center for Education Statistics (NCES) reported on the status and trends in the achievement of students. The authors report the gap in fourth-grade reading narrowed between White and Black students from 32 points in 1992 to 26 points in 2017. In math, the gap narrowed from 32 points in 1990 to 25 points in 2017. Among White and Latinx fourth grade students in reading the gap in 2017 was not significantly different than 1992, 19 points. For math, measures were the same as reading. The White and Latinx gap of 19 points in 2017 was the same as 1990.

de Brey et al. (2019) show for eighth grade students the gap narrowed in reading between White and Latinx students as they progressed through the grades, from 26 points in 1992 to 19 points in 2017. However, the White and Latinx gap at grade 8 math was 24 points in 2017, the same as 1990. Similarly, for eighth grade Black students reading gaps did not close with 25 points in 2017, not different than 1992. For eighth grade Black students, the gap in math began to close between White and Black students, 25 points in 2017 and 32 points in 1990. Gutierrez (2008) cautions educators against "gap-gazing" (p. 357) and the danger in watching numbers without a more thorough investigation of the issue. Gutierrez (2008) described the problem of gap gazing:

> These dangers include offering little more than a static picture of inequities, supporting deficit thinking, and negative narratives about students of color and working-class students, perpetuating the myth that the problem is a technical one, and promoting a narrow definition of learning and equity. (p. 358)

What is not part of the analysis of the gaps are the reasons for them. Some scholars have explained that group stereotypes can threaten how students evaluate themselves, which then can alter performance and in a larger sense, academic identity (Steele, 2003). Others have demonstrated that the issue as an opportunity gap surrounded by microaggressions and stereotypes of marginalized students that have resulted in learning outcome disparities (Irvine, 2010; Milner, 2013). Irvine (2010) described gaps that need to be closed:

> Gaps include the teacher-quality gap, the teacher-training gap, the challenging curriculum gap, the school-funding gap, the digital-divide gap, the affordable-housing gap, the health care gap, the employment-opportunity gap, the school-integration gap, and the quality child-care gap. (p. xii)

Milner (2012) suggests that "while achievement gap discourse in education usually focuses on students' scores on standardized tests, it also concerns student graduation rates, patterns in gifted and advanced placement, and other measurable outcomes that allow for comparisons between groups of students" (p. 694). Ladson-Billings (2006) provided a broader explanation of the achievement gap, resulting from multiple failures.

Ladson Billings (2006) depicted the gap as an "educational debt" (p. 5) due to an achievement gap stemming from historical, economic, sociopolitical, and moral decisions and policies. She provided the following description of the educational debt:

- The lack of an universal secondary education for Black students until 1968, the experiences of the assimilated Indian who completed boarding school could only attend historically Black colleges, and the exclusion of an equitable and quality education for Latinx students as seen in such cases as *Mendez v. Westminster* and the Lemon Grove Incident. (pp. 5-6)
- Inequities in funding between suburban and urban schools communicates the value placed on different groups of students. Historically, with the lack of schools for many communities of colors, Whites were not prepared to invest money to provide schools for marginalized students, viewed as "strange others" (p. 6).

Additionally, disparities in education also translates to decreased earning power and reflect the achievement gap:

- The sociopolitical debt as depicted in the disenfranchisement of Black, Latinx, and Native communities influenced their civic engagement and legislative representation. Their efforts to fight for a quality education for their children has not been successful. Affirmative action benefitted White women and aided the formation of the Black middle class. No bold policy actions have been taken on behalf of Black, Latinx, and Native communities (p. 7).
- Finally, Ladson-Billings wrote a moral debt "reflects the disparity between what

> we know is right to do and what we actually do" (p. 8) and the honor people owe each other. "But how do we recognize the debt we owe to entire groups of people? How do we calculate such a debt?" (p. 8). She suggested the greatest moral debt is to the indigenous people whose children continue to drop out of school more than any other group.

As described in the previous section, African Americans experienced hundreds of years of enslavement, laws preventing them from being able to obtain formal education, and a racially motivated implementation of modern-day laws have prevented any semblance of equity (Aghion et al., 2009; Blackwell, 1975; Span, 2015). These institutional structures were designed to prevent equitable access to the economy and to society, and the legacy of slavery is the degree of inequality that exists, as counties in the United States that were more heavily affected by slave labor are more unequal, not poorer in the present day (Anderson & Span, 2016; Bertocchi & Dimico, 2014). Dumas (2014) maintains that, "for many black children and families in the United States, Britain, and elsewhere, schooling is a site of suffering …that we have been least willing or able to acknowledge or give voice in educational scholarship and…educational policy analysis" (p. 2).

Latinx individuals represent deep roots in New Mexico from the 1500 to recent immigrants from Central America with variations in social class, generations, national identity, and versions of the Spanish language (MacDonald, 2004). While immigrants such as northern Europeans have been welcome in America and "integrated with full citizenship into the U.S. polity" (MacDonald, 2004, p. 307), people of Spanish descent have fought for freedom of speech, the right to assemble, and to obtain equity in schooling for their children.

Villenas (2012) asserts that Bilingual students are often viewed through a deficit lens and described as linguistically "'limited immigrants' in federal education policy". Additionally, several kinds of policies and perspectives marked the late 20th century related to the education of Latinx children; English only policies, the view that multicultural and affirmative action expanded opportunities for White people, and California's proposition 187 which stimulated the idea that undocumented immigrants exploit educational and health services taking resources from the "deserving true natives" (p. 13). The 21st century brought a backlash against ethnic studies and Mexican American studies with Arizona's Bill 2281 and Latinx's children's education continue to be fought within a global society that requires a new set of complex skills (Villenas, 2012).

Even after efforts of desegregation were implemented following the litigation of *Brown vs. Board of Education* (1954), schools were not able to provide an equitable education for many Black and Latinx students (Allen-Haynes et al., 2003; Notten, 2009; Orfield et al., 1997). Moreover, due to economic issues within districts, White flight, and a high concentration of underrepresented groups of students living in urban areas, there is still an uneven distribution of White and non-White students across all public schools (Gorard & Fitz, 2000; Owens et al., 2016). For almost 200 years since the birth of the United States, schools were segregated across the country, and research indicates that it has increased since 1990 (Djonko-Moore, 2016; Walker, 2000). According to Carnoy and Garcia (2017), there are several consequences, and as previously noted, schools that are highly segregated by race and socioeconomic status are more likely to have students who fall behind in mathematics achievement, as measured by longitudinal data from 1996 to 2013 on the National Assessment of Educational Progress (NAEP). Even when looking at schools that are desegregated, issues like tracking further segregates minoritized groups within the educational system (Vivian, 2017). New research has also indicated race and social class may interact with gender, causing damaging effects on the academic performance of Black boys (Carnoy & Garcia, 2017).

According to a recent study, nearly one out of every five schools enroll most non-White students, up from one in 20 in 1988 (Cookson Jr. et al., 2018). Segregation and achievement seemingly go hand in hand, as demonstrated by a 2011 study, which found Black students scored 30 points lower than their White peers on a NAEP grade eight mathematics test, and the large gap was attributed to how schools distribute their resources internally and treat students (Bohrnstedt et al., 2015; Flavin & Franco, 2020). This study analyzed nationwide school characteristics from the 2010-2011 school year to explore the associations between a student's race and their achievement level as measured by NAEP. Ultimately, Bohrnstedt et al. (2015) posited that the difference in achievement gap may be caused by an uneven distribution of key resources, lower expectations by teachers, tracking of Black students into remedial courses, and schools with a higher percentage of marginalized students tend to have higher shares of low-socioeconomic status students. Further, research has shown that due to multiple generations of struggle with socioeconomic status due to institutional barriers, underrepresented groups of students are still concentrated in high-poverty, low-achieving schools, while White students are more likely to attend high achieving, affluent schools (Flavin & Franco, 2020; Frankerberg et al., 2003; Orfield & Frankenberg, 2014). In addition to these examples of how trends have historically shifted, there are further inequities that exist for mathematics achievement.

Mathematics Achievement

Whether the achievement gap is one of success or access, public officials began to address the problem through policy changes that encourage school choice to combat a growing achievement gap. Unfortunately, this seems to have taken more resources out of the hands of underserved communities, as both charter and private schools are highly segregated by race (Whitehurst, 2017). Even within communities and demographic groups, there are still difference in mathematical achievement levels. For example, female students are more likely to hold negative attitudes toward mathematics, even at an early age (Froiland & Davison, 2016). Further, Ellison and Swanson (2018) posit that such a perception leads to lower achievement levels, as fewer females make significant gains in mathematics when compared to their male counterparts. Similarly, attitudes and lack of qualified educators in rural America seem to contribute to a growing divide in the academic performance of students (Irvin et al., 2017; Makur et al., 2019). Although issues of equity and student performance are tangled throughout history, an important focus must be on the improvement of schools.

According to Gillborn et al. (2017), progress has indeed been made to improve student test scores. However, a common misconception is that all students share the benefits of improving achievement levels, but the reality is that White scores are moving faster (Robinson, 2010). For example, a study of 8,315 students across geographic locations demonstrated that Black students maintained considerably lower mathematics and reading scores on standardized tests than White students, even though overall test scores increased on average for the schools (Assari et al., 2021). Although the researchers attributed this to parental education within the study, they also acknowledged confounding variables like socioeconomic status, teacher-student relationship, and teacher effectiveness. Despite the research that indicates several root causes of the mathematics achievement gap, several strategies have proven effective. First, instructional lessons need to be culturally responsive, and educators must recognize that children learn about the world in the context of their own cultures (Dee & Penner, 2017; Gay, 2013). To meet the varied needs of diverse learners, technology and digital learning have been able to provide personalization that differentiates instruction. Such a personalization leads to increases in student achievement not necessarily measured by standardized tests but rather the skills and concepts that use culturally responsive teaching to encourage students to be lifelong learners (Gay, 2013). As more schools utilize educational technology within their curriculum, Chuang (2016) confirmed that in order to utilize the elements of culturally responsive teaching that help students feel a connection to the material, schools need to personalize the learning process in a way that provides opportunities for interaction with the technology students are already using.

A key aspect of personalized learning, especially in mathematics, involves the flexibility for students to practice emerging skills by selecting the resources they need for support (Featherstone & Bayley, 2013). However, to support such a pedagogical trend, there needs to be a shift from data-driven achievement to culturally responsive practices, and educational technology may be able to provide the personalization needed to bridge gaps that currently exist (Fraser & Lefty, 2018). Xie et al. (2019) conducted a systematic review of articles published in peer-reviewed journals to discern where the trends of personalized education were heading. After setting inclusion criteria that limited the results to personalized learning in the education classroom, 70 articles remained. Taking a qualitative approach, the results demonstrated personalized learning is a key paradigm to educational technologies, and the categories of affection and cognition are the primary measured learning outcomes (Xie et al., 2019). These results give validity to the current direction of many districts that have provided technology to their students while moving toward online learning platforms that allow students to advance through the material at their own pace and move on only when they demonstrate proficiency in a content area (American Institutes for Research, 2016). Despite the progress, some gaps exist between students of different backgrounds on tests, access to courses, high school completion, and employment later in life (NEA, 2017).

Students' difficulty with mathematics did not start in an individual year; rather, the achievement gap in mathematics seems to widen the longer students remain in school. In 2017, NAEP published "The Nation's Report Card," which showed that only 39% of fourth-graders, 32% of eighth graders, and 23% of twelfth graders scored at the proficient level on standardized mathematics tests (para. 2). When less than one in four students is proficient in their mathematics abilities, post-secondary education is greatly affected. As a result, remedial classes now serve as the prerequisites for a diverse set of academic degrees because students need to develop application skills while mastering basic mathematical knowledge (Smith et al., 2015). Unfortunately, the data above demonstrate that an increasing number of underrepresented groups of students entering college are simply not ready for the academic coursework, which impacts college graduation rates (Diehl, 2017).

Addressing the increased number of underrepresented groups of students who take remedial mathematics has been a primary focus at universities nationwide. To improve students' skills for college-level expectations and college persistence rates, universities need to rethink some of their long-standing tenets of education and partner with secondary schools to create a more focused and relevant curriculum (Edmonds & Squires, 2016; Kaupp, 2017; Wang et al., 2017). Expanding the opportunity to be able to take college credit courses while in high school is a low-cost, feasible approach to accelerate coursework, especially for urban students. As these students transition to the post-secondary level, using a traditional textbook and assessment system to judge ability through summative examinations may not accurately gauge their understanding, so universities have begun to expand how they analyze student achievement (Blair, 2017). Despite this positive step, no matter how knowledgeable the instructor, a problem-solving method can only be implemented if the curriculum, textbooks, and the assessment system respect the value of this approach (Akhtar et al., 2015). All these realities that exist at the K-12 and post-secondary level point to a significant problem in our mathematics education: it is broken and must be fixed. The National Council of Teachers of Mathematics (NCTM) provided a framework of six principles to make mathematics achievement a reality for all students.

1. Teaching and Learning: Teachers must engage their students in meaningful learning experiences that provide a personalized approach to education. Further, teachers must be skilled at using instructional practices that are effective in developing mathematics learning for all students.
2. Access and Equity: Students need to have access to a high-quality mathematics curriculum that holds all students accountable and to high standards. Equitable access means accommodating differences to meet a common goal of learning and ensuring that underrepresented groups are adequately represented in advanced coursework.
3. Curriculum: An effective curriculum incorporates problems in contexts from both everyday life and the cultural understanding of students. Further, the mathematics curriculum must develop interdisciplinary connections among areas of mathematical study.

4. Tools and Technology: An excellent mathematics program includes the utilization of mathematical tools and technology as essential resources. These tools should be used to visualize abstract ideas that support teaching and learning.
5. Assessment: Effective assessment should include a variety of strategies and data sources, provide feedback to students, and guide instructional decision and program improvement.
6. Professionalism: Educators must hold themselves and colleagues accountable by consistently working to increase the impact they have on students while supporting a culture of professional collaboration and continuous improvement. When students can take classes that interest them and better connect with the community, they are much more likely to take a personal stake in the classroom content. (2015, pp. 4-5)

The solutions to a broken system are not immediate and face a variety of challenges; it is crucial to implement a multi-layered approach to support students and their families holistically by helping school personnel acquire the skills to teach in culturally responsive ways (Howard, 2019). In addition to restructuring the curriculum and pedagogy to meet the needs to students, there is both increased pressure on teachers to have students perform well on examinations and the additional scrutiny on school districts and public universities to incorporate cutting-edge technology with limited funding, it might seem like an impossible task. One promising, cost-effective approach involves the utilization of e-learning (Zhang et al., 2004). Schools that have implemented personalized learning practices are seeing their underserved populations make greater progress when compared with their peers and students who started behind are now catching up to perform at or above the national average (Pane et al., 2015). A major benefit of such programs is a teacher's ability to analyze data in real-time and provide effective, immediate feedback to make instructional decisions (Pane et al., 2015).

As more research is conducted into how students learn, reforms and initiatives across the country are continuing their focus on differentiated instruction. Although multiple attempts at differentiation have been implemented over the last few decades, technological advances are making it possible for teachers to provide a more personalized approach to education. Especially in urban schools, students' diversity presents challenges to the traditional school model. It is a reality that culturally specific characteristics like language, family, and social issues are found to be predictive of success and, especially for African American males, incorporating culturally relevant experiences within the classroom dynamic is paramount to closing the achievement gap (Patel et al., 2016; Ransaw & Majors, 2016). There is no longer the possibility of pushing back against the changes that will inevitably occur; schools must adapt to their clientele. Otherwise, we continue to propagate a system that believes "knowledge is a gift bestowed by those who consider themselves knowledgeable upon those whom they consider to know nothing," further strengthening the ideology of oppression (Friere, 1972, p. 164). As educational leaders and politicians make efforts to break the cycle of oppression, they look to teaching methods to aid such transformation. By no means does pedagogy supersede the importance of building relationships with students or creating a coherent curriculum aligned with standards that uphold high expectations, as both of these concepts have proven effective, especially for disadvantaged students (Demie, 2015; Duckworth & Yeager, 2015). Instead, pedagogy and classroom structure work with these concepts to provide a rich, rigorous, and supportive atmosphere for all students. To facilitate such a shift, mathematics instruction should be transformed to better meet the needs of each student.

Mathematics Instruction

Educating students requires more than just an adult in a room with a set of standards dictated by a curriculum. Increasingly, research has indicated that pedagogy, content knowledge, and differentiation are all crucial to developing mathematical and critical thinking skills among students (De Corte, 2003; Škoda et al., 2016). In other words, there are multiple facets of effective instruction. Teachers need to be content experts, pedagogically knowledgeable, but also have the wherewithal and cultural understanding to reach students of diverse backgrounds and ability levels. Such a shift away from teacher-centered instruction brings about two issues that must be addressed. First, schools must find the instructional and technological tools that allow teachers to ensure students are learning at a level on track with the dictated curriculum. Secondly, regardless of ethnicity, gender, or any other demographic marker, the American public education system must ensure that all students are learning at the same level.

Depending on the classroom, effective instruction can take on vastly different appearances. Latif (2014) purports there is one-size-fits-all approach to mathematics education, but to be effective, the curriculum must be guided by a clear set of content standards that are grounded in a shared vision of teaching and learning. Without such clarity of understanding, all stakeholders will not be on the same page, and the unfortunate result is broken gaps in education for students. An important distinction to make on Latif's work is that common standards do not correlate to a single instructional strategy (De Corte, 2003). Instead, teachers can utilize a variety of approaches to meet the unique needs of their students, as students in different geographic areas with different backgrounds will require differing strategies. Although they have the latitude to utilize varying strategies, teachers must adhere to data-driven practices, as “the most significant factors associated with students’ mathematical achievement are pedagogical” (Boston & Wilhelm, 2015, p. 835). As technology changes, effective instruction has been greatly affected, as teachers can analyze data in real-time, providing immediate feedback that guides the daily lesson. Utilized appropriately, digital technology can be transformational, enhancing student learning by developing problem-solving skills, critical thinking, and creativity (Jung & Conderman, 2015; Marpa, 2020; Selwyn, 2016). Currently, one of the most popular shifts in instruction has been to create a student-centered classroom environment. Rather than being the “sage on the stage” implementing curriculum materials to students, teachers are now the “guide on the side,” acting as partners in the facilitation of curriculum materials (Jones & Pepin, 2016; Pepin et al., 2017). Although the recent changes to instruction have resulted in classroom environments that are less static with teachers who are more cognizant of effective pedagogy, the classroom remains inequitable for many students. Technology offers a variety of solutions, among which includes blended learning.

Blended Learning

For the last decade, blended learning has looked very different depending on the implementation model, geographic location, and available technological tools. Naturally, there is often some confusion within the educational world when answering the question “What is blended learning?” A summary of Horn and Staker’s (2014, para. 3) definition of blended learning is as follows:

> Any time a student learns, at least in part, at a supervised brick-and-mortar location away from home and, at least in part, through online delivery with some element of student control over time, place, path, or pace. The modalities along each student's learning path within a course or subject are connected to provide an integrated learning experience.

Blended learning is not an attempt to replace the teacher. Instead, it is a way to allow the role between teachers and students to be defined differently to provide a fuller educational experience. Such a paradigm shift includes moving from teacher-centered to student-centered instructional strategies.

Teacher Centered Instruction

Throughout the history of American public-school education, the most common methods of instruction have been teacher centered. Although there are many reasons for this, the most rational explanation is that it is the cheapest, most efficient way to educate all children. From the inception of teacher-centered instruction, critics have argued that such an approach to education creates passive learners who are unable to critically think because the structure of the classroom discourages the pursuit of learning and individual inquiry (Dewey, 1916). Standardized tests and increased accountability for both teachers and students have only reinforced the need to present a large amount of information within a prescribed amount of time. With the pressure that goes along with standardized tests, many teachers feel as if student-centered models of instruction are not feasible, as they may take extra time and may not be consistent every year (Serin, 2018). Additionally, findings have indicated that a teacher-centered approach results in higher achievement overall, especially for emerging bilingual students whose primary language is not English. (Chall, 2000; Emaliana, 2017;

Kassem, 2019). Although teacher-centered instruction can prove to be effective for students on standardized tests, the landmark work of Madeline Hunter shows a need to provide students with learning experiences that foster a sense of creativity and critical thinking (Hunter, 1994). Hunter's work undoubtedly provided a template for teachers to develop a rigorous lesson plan, but it also over-emphasized direct instruction which failed to differentiate instruction and prevented students from having the agency provided through choice within a lesson or assessment (Stallings, 1985; Kallick & Zmuda, 2016) Further, the full picture of achievement may not be adequately gauged by a single standardized test, and researchers remain critical of the assertion that Hunter's method raises test scores (Ramsay, 1990; Slavin, 1986; Stallings & Krasavage, 1986). Specifically, the studies by Slavin and Stallings and Krasavage (1986) followed two of Hunter's schools to see if learning was affected long-term. The results indicated that student growth may have been tied more to the competency level of teachers rather than the structured method in which they engaged students during class time. Ultimately, the researchers cautioned against any wide-scale implementation of Hunter's work due to its emphasis on recall and subsequent inability to engage students in higher-order thinking.

Measuring true student learning requires that students engage and can demonstrate their understanding. Often, teacher-centered strategies employ choral response under direct instruction, which does not allow students to exhibit output behaviors; to determine if students are learning, they need to be able to have a perceivable act of mastery (Hunter, 1994). Rather than using the "tried and true" instructional strategies that have led to a dominating class culture, instead "think a little about the learners' cultural identity and about the respect that we owe it in our educational practice" (Freire, 2005, p.127). As the culture of public education continues its trend toward increased diversity, it may be necessary for schools to move toward a student-centered model that is better able to personalize the learning experience.

Student Centered Instruction

Throughout the past fifty years, public-school classrooms have become more diverse and held to increased standards with reforms from the federal, state, and local levels. In order to create the type of environment students need to achieve at high levels, teachers must take a democratic approach to education and center instruction on students' unique needs. The Education Alliance at Brown University (2018, para. 2) defines student-centered instruction as follows:

> Student-centered instruction differs from traditional teacher-centered instruction. Learning is cooperative, collaborative, and community oriented. Students are encouraged to direct their own learning and to work with other students on research projects and assignments that are both culturally and socially relevant to them. Students become self-confident, self-directed, and proactive.

By utilizing social strategies within the classroom, students can learn in ways that are unique to their interests and ability levels while connecting on a deeper level with the community and those around them. Vygotsky (1978) posited that learning occurs most effectively when children develop cognitively through interactions with both adults and more knowledgeable peers. Especially for multi-cultural students, such interactions are even more important, as they allow these students to learn through experimentation and receive constructive feedback, both of which are characteristics of critical thinking (Darling-Hammond, 1997).

Although student-centered instruction can take many different forms, two common strategies are flipping the classroom and utilizing digital learning tools to create personalized instruction for students (e-learning). Flipping the classroom essentially changes the way the daily lesson is structured. Consider a mathematics classroom; instead of traditional instruction, where students take notes during class and do practice problems at home, that process is “flipped” (Gilboy et al., 2015). Students are assigned videos to watch or pages to read, take notes on the material, and come to class ready to work on practice problems. Such a learner-centered approach allows a teacher to differentiate more easily, as there is additional time to design class activities using all levels of Bloom’s taxonomy (Gilboy et al., 2015). Due to the added focus on individualized learning, students in flipped classrooms experience improved academic performance, especially among those who need more individualized attention (O’Flaherty, 2015). Although teachers and students have been successful with flipped classrooms, there are still some critical issues that need to be explored. Because there is an increased focus on completing work during class, there are fewer opportunities to provide situations that develop critical thinking; thus, this approach to teaching may not contribute to building lifelong learning or other skills needed to be successful in the 21st century (O’Flaherty, 2015).

While every pedagogical strategy has its drawbacks, student-centered instruction allows for a great deal of individualization. When personalizing the learning process, researchers posited that student achievement growth exceeded that of a comparison group and students with lower starting achievement levels experienced growth rates superior to “on-track” peers (Pane et al., 2015). As more districts are encouraging personalized learning due to its possibilities and successful track record, the following question must be asked:

What type of personalized learning has proven most effective? As the technological options afforded to teachers has increased exponentially over the last decade, more teachers are attempting to utilize technology for personalization than ever before. Further, instructional practices that support competency-based learning received positive remarks from teachers, and more importantly, students were more likely to report that their mathematics instruction was both student-centered and required complex, higher-order thought processes (Pane et al., 2015). To investigate these claims, this study sought to determine the impact of educational technology on mathematics achievement and how digital learning tools can help create personalized learning environments for ninth grade students. Understanding the nature of learning domains is significant to the success of personalized learning.

Learning Domains

Throughout the past 50 years, there have been innumerable initiatives coming from the federal, state, and local levels regarding education. As previously mentioned, the most recent push has included personalizing the learning process, but what are the variables that lead to success for some programs and failure for others? Differentiating between the characteristics that prove most effective is essential, especially when operating in urban environments that have historically experienced limited resources. Hampered by funding, how schools deploy instructional resources to provide concrete alternatives to traditional structures ultimately contributes to increased student achievement, especially in urban areas (Miles & Darling-Hammond, 1998). Perhaps part of these mitigating factors includes how schools choose to focus on the three domains of learning.

In Bloom’s (1956) taxonomy of learning domains, research demonstrated that people learn content through multiple modalities. The study outlined three domains: cognitive, affective, and psychomotor. In both the past and present, much of the focus from schools has been placed on the cognitive domain, as this is most directly related to the content taught in schools. Increasingly, however, educational research has begun to stress that a balance of each domain is necessary. For example, in a random sample of 418 students in an international secondary school, students were given a 13-question assessment to measure higher-order thinking skills (Saido et al., 2018). In these schools, which were primarily focused on the cognitive domain, most students were in the lower level of thinking skills. Moreover, the researchers indicated that students need the opportunity to think like experts in the field, so they should have the opportunity to be engaged in the real-world application of the material, as this positively effects student enthusiasm and motivation (Saido et al., 2018). Thus, as schools continue to increase the utilization of technology, they must be careful that all domains of learning are supported by the program chosen. An approach that makes use of students' strengths and interests is more likely to involve them in partnerships that help all students achieve their potential (Friend & Caruthers, 2009). Although all the domains are often attributed to Bloom (1956), his landmark research predominantly addressed the cognitive learning domain that has been the primary focus of school-wide reforms across the nation.

Cognitive Domain

Often seen as the traditional purpose of education, the cognitive domain is the avenue through which nearly all initiatives are implemented. Within the research done on the cognitive domain, Bloom (1956) developed a taxonomy widely used by educators to classify the levels of reasoning skills required within a classroom setting. Students traditionally start on the bottom of a hierarchical pyramid, and the job of the school is to move students up the taxonomy as they progress in their knowledge. Without a doubt, Bloom's taxonomy has had a considerable impact on educational thought and practice and is widely considered the guiding light to curricular changes (Seddon, 1978; Stanny, 2016). Due to this importance and widespread application in teacher preparation coursework across the nation, it is crucial to understand how each level impacts the learner, regardless of the instructional approach.

Knowledge

In the first level, students demonstrate the ability to recall specific information from a lesson (Bloom, 1956). For example, memorizing dates in a history lesson or being able to recite the quadratic formula are examples of students demonstrating their basic recall knowledge. This first level is critical in developing students' higher-order learning, as it can best be enhanced through building a foundation of factual knowledge (Agarwal, 2019). Although critics argue that there are more effective ways for students to develop the knowledge base and that emphasis on pure recall does not lead to higher-order thinking skills, the vast majority of instruction is created to provide a basic level of information for students to be exposed to proceed to the next level of Bloom's taxonomy (Verenna et al., 2018). Once a foundational knowledge has been produced, educators can delve deeper into the subject matter in order to support increased levels of comprehension.

Comprehension

Being able to recall information may be necessary, but it is vital to be able to understand the information as well. Within this level, students must be able to interpret information and make use of the material without seeing its full implications (Bloom, 1956). This level is often overlooked by well-meaning educators, as students who are familiar with the school setting have become adept at restating their teacher without adding original thought. For this reason, the role of comprehension on performance level assessments cannot be understated (Verenna et al., 2018). As schools begin to digitize assessments with the hopes of analyzing data, accurately creating questions that distinguish between various levels has been challenging, and there is a greater need to gauge one's ability to apply the information learned (Assaly & Smadi, 2015).

Application

Bloom (1956) defined this level as the ability to employ abstractions to explain, describe, or predict outcomes using concrete situations. In order to make the learning process meaningful, schools have attempted to incorporate problem-based experiences within the curriculum (Savery, 2015; Stanny, 2016; Verenna et al., 2018). Unfortunately, many of these opportunities are forced, creating situations that are not relevant to the student and do not inspire additional connections to their lives. One of the more promising approaches, however, involves using team-based learning and collaboration to solve a problem; moreover, much of this collaboration can and should take place virtually to help students learn effectively (Quinton & Allen, 2014). As students continue to progress within the hierarchy of the cognitive domain, they begin to be able to exhibit higher order thinking skills.

Analysis

This is the first level that students are expected to truly think for themselves using prior knowledge. According to Bloom (1956), such a stage represents the breakdown of communication into its individual parts to demonstrate a relationship between ideas. Developing lessons for the subsequent levels proves increasingly difficult because students are naturally at different locations due to their ability level, shared experiences, and cognitive functioning (Stanny, 2016). As a result, many curriculum writers have thought to simply incorporate different verbs into the assessments to increase higher order thinking skills. Put simply, such an approach is not effective because no teacher can adequately differentiate for each student's current ability level (Goyal & Rajalakshmi, 2018). For this reason, it becomes important for schools to seek technological solutions that can provide an easier method of assessing students and providing immediate, constructive feedback.

Synthesis

After information can be analyzed, the next step includes putting together individual pieces to form a whole argument (Bloom, 1956). An important distinction is the originality of such a situation. In short, a hallmark of the synthesis level is to create new meaning or structure out of an existing body of knowledge. Although not the pinnacle in Bloom's original work, revisions by Krathwohl and Anderson (2009) argued that synthesis (creating) is more indicative of a complete understanding of a topic. Moreover, at the time Bloom's taxonomy was developed, there were some weaknesses and practical limitations within the research. Since publication, additional psychological and educational research and subsequent theories have supported the alteration of synthesis and evaluation within Bloom's original taxonomy levels (Amer, 2006; Verenna et al., 2018).

Evaluate

In the final level of Bloom's (1956) original work, students are expected to make judgments about the value of material and methods for given purposes. One of the major struggles to reach the summit of experiential learning is to create relevant, authentic assessments in an effective manner (Halupa, 2017). Instructional technology may be helpful in combating such obstacles, as it allows students to experience new concepts to provide a more fulfilling educational process.

Progressing through each level of Bloom's taxonomy demonstrates an ability to understand the rigor and relevance of a content area. Moreover, it allows students to develop their metacognition skills though scaffolding; if students become aware of their thinking processes, then they will be able to create meaning in the presence of a real problem (Agarwakm 2019; Goyal & Rajalakshmi, 2018; Holton & Clarke, 2006). To be successful in all aspects of life, however, the cognitive domain of learning is not self-substantive. On the contrary, the affective and psychomotor domains include skills that are readily needed in the workplace (Bandaranaike & Willison, 2015). Moreover, to unlock the vast potential of cognitive skills, schools need to develop a deeper understanding of the affective domain to promote the concepts of emotional work and life readiness.

Affective Domain

There is little doubt that being able to grasp the various academic concepts within a school setting is necessary to achieve success at the secondary and post-secondary levels. While the cognitive domain impacts the process through which an individual can understand a topic at a high level, the affective domain is reflective of the values, motivations, attitudes, and feelings one has toward learning and the educational environment (Hart 1989). All of the aforementioned attributes greatly impact learning and support the cognitive domain; the reality, however, is that so much time is spent by teachers and educational reformists on the cognitive domain that the symbiotic relationship between each of the learning domains is overlooked (Iozzi, 1989). It was this disconnect that caused researchers to develop a second domain to explain the successes and failures of certain students. The seminal research from

Krathwohl et al. (1965) posited that there are five categories that make up the affective domain: receiving, responding, valuing, organization, and characterization. Each level is a piece of a hierarchy that is based on internalization, and movement forward creates more involvement, commitment, and intrinsic motivation for the student. Green et al. (2017) quantified these categories by conducting research with a control and treatment group at Preston University. The results from the study demonstrated there was a significant relationship between affecting learning conditions and students' academic achievement when students were able to progress through each hierarchical level.

Receiving

The lowest level of the affective domain occurs when an individual is simply aware of the existence of ideas in the learning environment (Krathwohl et al., 1965). Although not sought after as a final piece of understanding, the receiving level is a necessary one, as information cannot be recalled is it was never received in the first place. During this stage, how content is projected, and the attitude being observed is crucial to developing a consistent framework for future levels in the hierarchy (Pierre & Oughton, 2007). Passive interaction with material does not lend itself to learning, so it is crucial to being to actively incorporate students into the learning process. Such a goal is accomplished in the second level: responding.

Responding

Once presented with a stimulus, the next level includes reacting to it in a positive way (Green et al., 2017; Krathwohl et al., 1965). What distinguishes this level from its predecessor is the amount of risk it requires of the student. Often, such a response is completed in a public manner, so creating an environment that supports the beliefs and values of all students is crucial to facilitating the progression of this level (Schoenly, 1994; Krathwohl & Anderson, 2009). Unfortunately, environments that are inclusive of all students are not commonplace. When only a certain set of students feel rewarded for their behaviors within a classroom, those who are not rewarded feel isolated; for this reason, underrepresented groups are less likely to progress past this level of the hierarchy (Benson, 1987). Once an individual can respond appropriately to a stimulus, they can begin to assign it value.

Valuing

Operationally defining value can be somewhat tricky, and Krathwohl et al. (1965) had it range from accepting the stimulus for what it was to a level of commitment that included an intrinsic sense of responsibility. In the educational realm, valuing cannot occur if a relationship has not been formed; only when there exists mutual respect can each party begin to value the overall purpose of a content area (Neumann & Forsyth, 2008). Once a relationship has been established, there is a great deal of potential to improve how all stakeholders perceive the shift to supporting the affective domain. The ultimate success or failure during this process is greatly impacted by the kinds of methods teachers use and whether those methods are direct or indirect (Reigeluth, 2013). After assigning value, a person can begin to organize their sense of value in an ordinal way; one value is more (or less) important than another.

Organization

If one were to characterize affective domain skills as higher-order thinking, the organization level would begin to signify such a shift, as it deals with an individual considering multiple stimuli, relating them to their current experiences, and then altering one's value system (Krathwohl et al. 1965). Further, it deals with the process of comparing values to create an order for them. Thus, an intrinsic priority is created based on a person's combination of interests, passions, and life experiences. For this reason, it is crucial to address the affective domain in school. Left to their own devices, students without a feeling of connection to the school system are more likely to develop a priority that does not support their educational goals (Tennyson & Nielsen, 1998). In order to sustain learning in the affective domain, teachers need to hone communication skills; namely, immediacy, disclosure, assertiveness, and responsiveness can create an affectively based domain (Rodriguez et al., 1996; Verenna et al., 2018). Like many aspects of life, there is a difference between knowing and doing. Within the affective domain, the organization acts as the "knowing" piece and characterization acts as the "doing" piece.

Characterization

This is the highest level in the hierarchy of the affective domain model. Based on the prior levels, certain values are internalized, and an individual must act following these values (Krathwohl et al., 1965). In its simplest description, characterization involves living one's truth, internalizing what is most important and letting those beliefs guide behavior. For many students, however, life is about the latest impulse, and basic emotions like pain and fear tend to take precedent over their educational needs. As social beings in a social environment, students need the wherewithal to have a common set of beliefs that positively impact the good of the whole (Carberry & de Rosis, 2008). As educators seek to fully commit to racial equity and attempt to enact changes that are reflective of the needs of all people, we must prepare students emotionally for this undertaking (Boylan & Woolsey, 2015). Such a goal is lofty and can only be accomplished if students have reached the characterization level of the affective domain hierarchy. Creating initiatives and reforms that only address the affective domain is difficult to support, as they initially do not seem to impact student learning or narrow the gaps of success or access. Despite this perception, student potential cannot be tapped until we begin to support the emotional well-being of our students and teach them how to interact empathetically with others. If the cognitive domain is indicative of the information students know and the affective domain reflects how students feel about their learning, then the last domain describes the physical interaction students have while in the learning environment.

Psychomotor Domain

In today's world, the practical application of skills learned is a crucial aspect of the jobs available to the next generation of students. According to Romiszowski (1999), psychomotor skills are evident in the daily activities of every occupation; moreover, attaining such skills is essential if one hopes to avoid the socioeconomic shifts that occur due to automation in the workplace. Put simply, even if a person was to demonstrate proficiency in the cognitive and affective domains, Simpson's (1971) landmark research demonstrated that a weakness in the psychomotor domain results in a lack of motor skills and coordination that negatively impact one's ability to maintain success in the workforce. To understand how this domain can impact learning and personalization within the educational environment, it must first be operationalized.

Dave: Psychomotor Domain

When considering the psychomotor domain, it is important to note that three primary revisions are widely accepted. The first is the simplest and represents the various levels of competence while performing a skill (Dave, 1970). Thought of like learning to play an instrument, this version of the psychomotor domain starts with the process of imitation. As the person begins to manipulate the characteristics of the skill, precision is developed. During the level of precision, a person can perform a skill with a high degree of accuracy without intervention. Next, articulation allows a person to apply a skill to address a certain problem situation. Finally, once a person can act without thought and the skill is second nature, it has been fully naturalized. Especially in the field of education, as students are honing their expertise in a particular content area, these stages are often present, but they are oversimplified (McBride et al., 1990). While Dave's approach may be appropriate when addressing behavior within the classroom, it may not be as effective when addressing the unique needs that districts have when implementing a personalized approach to learning (Sottilare & LaViola, 2015). For this reason, other perspectives must be considered.

Harrow: Psychomotor Domain

In order to address some of the gaps in Dave's work, researchers began to focus on the physiological effects that occur within the development of learned capabilities. Harrow's research sought to provide support for students who were developing proficiency in the cognitive and affective domains but still seeking to provide a connection to the real world (1972). Consider the process of learning about the culture in another country. One could study the demographic data, imports and exports, and language utilized within that country, an indication of the cognitive domain. By investigating conversations with first-generation immigrants from that country, students are meeting an affective objective. On the other hand, if they were taught a set of dance steps common in that country's cultural celebration, students would be progressing through stages of the psychomotor domain (Harrow, 1972). Such a process would occur as follows. Upon first listening to the music, students may have an involuntary reaction of tapping feet, indicating reflex movements. As they watched the dance steps being performed, students would use their current fundamental knowledge base and their perceptual abilities to react to the environment. As students practiced the dance steps, they would exhibit both physical abilities and skilled movements as efficiency and accuracy begin to be improved. Finally, after they no longer needed help from others, they would be able to exhibit non-discursive communication. These stages of Harrow (1972) are accurate when describing an overtly physical interaction, but it does not adequately explain the stages of development that occur as students are interacting with a cognitive tutor or other educational technology (Brown et al., 2017). If the psychomotor domain is integral for students to truly understand the phenomena to which they are exposed, there must be another interpretation that can provide a more accurate depiction.

Simpson: Psychomotor Domain

More academic, Simpson built her taxonomy on the work of Bloom. Like the work of the prior researchers, Simpson (1972) was focused on the utilization of motor skills and how they can be effectively coordinated to produce a positive result. What was different, however, was the focus away from the purely physical and toward the progression of mastery that occurs from observation to invention (Sottilare et al., 2016; Sottilare et al., 2017). Although her research was completed before the integration of any ITS models, Simpson’s approach fits seamlessly. The first level is perception, where students utilize their sensory clues to guide their physical reaction (Simpson, 1972). Next, the mindset signifies one’s readiness to act. As an individual begins the process of guided response, the learned responses created from habitual actions form a mechanistic approach. As a person proceeds through the intermediate phase, they can perform complex overt responses within efficiency and accuracy. Finally, the highest levels of the psychomotor domain are adaptation, where the learned skills can be modified to react to a new set of stimuli and origination, where an entirely new response is created based on a specific problem. Simpson's explanation is highly indicative of the skills needed by students who are interacting with an Intelligent Tutoring System and highlights the importance of a program's need to access the exact knowledge state and be able to provide opportunities for cognitive tutoring (Sottilare & LaViola, 2015). This personalized approach can help students ascend the levels of their psychomotor domain because each student's learning is individualized by their own experiences and knowledge base. As each of the domains has been discussed, they all exhibit structures that are important to student learning. Unfortunately, many of the initiatives applied to schools across the nation have primarily given attention to only one of the three domains of learning, the cognitive.

Focus of Reforms

Regardless of geographic location, schools have attempted to address inequality within their district, and most alterations have centered on content-based instruction. This is not solely due to the school district; almost all state-based and federal reforms have tied finances or notoriety to a high-stakes test. For example, under the No Child Left Behind (NCLB) law of 2001, states had to ensure that students were tested in both math and reading in grades 3-8 and once in high school. The most efficient way to roll out such changes was to enact a curriculum that essentially taught to the test; as a consequence, schools shifted toward the cognitive domain and abandoned the affective domain (Lee et al., 2018). The initial intent of the NCLB was to hold schools accountable for the performance of underrepresented groups of students and provide a better picture of the type of education received in areas that had not experienced any form of accountability. Unfortunately, because affective constructs were not tested by the state, most classroom teachers did not devote their attention to developing these skills. As a consequence, students are not given feedback on what may be the missing piece of the puzzle for reformers (Hall, 2011). Research has shown that at the very least, the affective domain, which consists of students' content related attitudes, values, beliefs, and dispositions, is perhaps even more significant than cognitive variables (Popham, 2011). A study of secondary mathematics students reaffirmed Popham's and Hall's research, as students demonstrated an aversion to mathematics due to the subjective assessment's inability to measure beliefs, attitudes, and emotions within the learning process (de la Oliva Fermandez, 2020). Although the motivations of reformers may be pure, their transgressions are many.

Perhaps the best example of how the affective domain is impacted by education is the comparison between a first grader and a high school senior. The first grader who is anxious to come to school because they want to explore, discover, and learn transforms into an apathetic, grade-driven teenager with little concern about how the content makes them feel. Yes, some of this is due to hormones and outside influences, but a contributing factor is due to the very structure of schools. Students need to have both motivation and desire to learn; without these two affective characteristics, there can be no true learning (Stiggins, 2005). What then, are schools to do? Surely there is not an argument to remove the cognitive pieces of the school curriculum. However, in an age where there are seemingly not enough resources to meet the diverse needs of every student, districts need to look to technology to bridge the widening gap.

Personalized Learning

As public-school districts across the nation have sought to develop initiatives to narrow the achievement gap within their school district, there has been a rise of personalization in the form of classroom differentiation. Initially supplemented with games and drills based on a behaviorist learning philosophy, cognitive tutoring systems attempted to define competency using Skinner's landmark research: the division of content into a large number of very small steps, where reinforcement must be contingent upon the accomplishment of each step (1938; 1954). As cognitive tutoring gained traction, many newer tutoring models began to implement theories of constructivist teaching, where students were involved in problem-based learning and could take a hands-on approach to their construction of knowledge (Savery & Duffy, 1995). The proverbial needle is not moving fast enough, however; all scores are indeed rising for each demographic, but even though all students are experiencing improved test scores, White students' scores are increasing at a higher rate (Robinson, 2010, p. 271).

As technology became more advanced and schools attempted to meet the diverse needs of their students, adaptive learning has begun to truly personalize how knowledge is distributed. Adaptive learning software is an advanced form of a cognitive learning model, and students can be placed at their specific knowledge state rather than an arbitrary location of the curriculum. Specifically, Doignon and Falmagne (1985) define "the knowledge state of an individual with respect to that domain … as the subset of all the questions that this individual is capable of solving" (p. 181). Further, Aleven et al. (2015) assert that an Intelligent Tutoring System (ITS) that guides students' current ability level can help them to become better learners by comparing the growth in software from their initial study in 2009.

Their research evaluated 18 ITS structures to determine how well they were able to integrate curriculum and deliver to students without a working knowledge of programming. Each of the 18 structures were used in real educational studies with a pretest/posttest methodology that has garnered statistically significant gains (Aleven et al.) Combined with a declining cost of implementing ITS technology, such successful quantitative results have unlocked the potential of utilizing adaptive learning software. Schools started to implement one-to-one initiatives with the hope of raising student achievement, modernizing the classroom environment, and positively affecting both student motivation and engagement (Harper and Milman, 2015).

Despite the enormous potential of providing students with technological devices that utilize cognitive tutoring as a form of instruction, the quality is dependent on the program chosen. In other words, if the adaptive learning software does not adequately place a student at their knowledge space and if the cognitive tutor model cannot remediate when a question is misunderstood, then success is nearly impossible. According to Bailey et al. (2013), the same utilization of data to personalize online shopping that shows us only the consumer items we are likely to purchase has come to education. Thus, when choosing an Intelligent Tutoring System, schools must only consider software that adapts to the individual in a way that can engage students by tailoring instruction to deliver “just-right” content (Vander Ark, 2012). Done correctly, Intelligent Tutoring Systems can be woven into the fabric of the public education system to provide a more equitable environment for students who are seemingly held back not by their knowledge but rather by their geographic location. For this reason, software that utilizes cognitive tutoring offers the most promise to promoting equity among mathematics students due to its ability to individualize the entire learning process.

The SLP hopes to realize such potential, but where does it fit into the existing body of research? First, a cognitive tutor is a type of Intelligent Tutoring System (ITS) that can provide individualized, immediate feedback to students as they work through the curriculum online. Further, adaptive learning software can determine the exact location of a students' knowledge state through the sequencing of questions. The SLP is an example of an ITS because, through the utilization of pretests, it can place students at their level of understanding while providing support to progress through the district-created curriculum.

Theoretical Basis for Intelligent Tutoring Systems

As personalized learning has developed from a concept of differentiation within the classroom to the utilization of technology, there have been various theories that have dictated its facilitation. The two most prevalent, however, are Knowledge Space Theory (KST) and Adaptive Control of Thought-Rational (ACT-R). These ideas and the research supporting them have made significant contributions to the field of personalized learning through the utilization of technology. Specifically, in mathematics education, ITS models have found a niche while supporting KST or ACT-R to various degrees of success.

Knowledge Space Theory

When personalizing the learning process, the software used must have the capacity to learn and adapt based on user responses. Knowledge Space Theory (KST) is the theoretical idea behind such an adaptive nature of mathematics software and was developed by the tandem of colleagues, Jean-Paul Doignon and Jean-Claude Falmagne. At its heart, KST is the process through which an Intelligent Tutoring System can capture and determine what a student knows. Specifically, Doignon and Falmagne (1985, p.176) define "The *knowledge state* of an individual with respect to that domain … as the subset of all the questions that this individual is capable of solving." Within the mathematics classroom, it is virtually impossible for a teacher to immediately assess all students, provide feedback, and place them in the level of instruction they need. KST has an appeal for proponents of personalized learning through technology due to its ability to demonstrate prerequisite skills, and the work by Doignon and Falmagne (1985) provided the foundation for later attempts to develop algorithmic procedures that assess content knowledge.

With the many reforms and initiatives pushed through the federal, state and local levels, districts' advocacy for personalized learning has created a lucrative market for online software programs. Particularly in mathematics, where much of the content is sequential and utilizes a spiraled approach to teaching, computer algorithms may be the most effective way to determine the knowledge state of a student (Falmagne et al., 1990). Traditionally, successful teachers would tailor their lessons based on what they believe their students knew. Although the process to gauge such knowledge varies widely, determining where the average student was at in terms of prior and current knowledge would lead to wide-scale differentiation. This method is sufficient when attempting to educate the masses, but it does not address the diverse needs of *every* student. The concept supporting KST mimics that of the teacher differentiating to a group of students; the only difference is that KST can provide immediate and current feedback about student knowledge (Doignon & Falmagne, 1999). Much like the assembly line system revolutionized the automobile industry, principles of KST are attempting to provide efficiency and accuracy to the evaluation of student knowledge, which researchers determined can be used as assessment tools (Falmagne et al., 2004).

Ideally, every student would be provided with personalized education, and if they struggled, a one-on-one tutor would be provided. Adaptive learning software that is backed by KST functions much like this example. First, a student's knowledge would be mapped out with an assessment cycle that continuously determines the mathematical concepts that a student either knows or does not know. Next, the program would provide the teacher and student with feedback. Eliminating the time that it would take a teacher to assess and plan makes the educational process much more efficient. Further, determining the knowledge space for a mathematics allows some students to proceed more quickly through the material while also providing additional structure for learners who are behind their peers (Falmagne et al., 1990). This description is a working definition of a personalized learning environment, and it is the current vision of many school districts.

One of the first implementations of an ITS backed by KST was the Relational Adaptive Tutoring Hypertext (RATH). The course chosen for the web-based tutoring software was elementary probability theory, due to consistent struggles by students and the need for remediation and additional support (Hockemeyer et al., 1997). The assumption was that any course could be added into RATH, provided all teaching materials and assessments could be structured in a web-based manner. Although RATH bridged the gap in bringing psychological theories into a working tutorial system, Hockemeyer et al. (1997) had two main recommendations:

1. Students have some prior knowledge of every subject. Rather than assuming a new student has an empty set for a knowledge state (zero prior knowledge), the researchers indicated the need to include an initial assessment to determine the actual knowledge state.

2. Feedback provided to the student needs to be more detailed than correct/incorrect. To model personalized tutoring, there need to be more supports to ensure success, and immediate feedback eliminates the repetition of mistakes.

From the research and conclusions done with RATH, other ITS models were created and implemented, experiencing similar successes and struggles. In a 2006 conference, Conlan, Hampson, O'Keefe, and Heller presented a series of research-based case studies where KST ideas were implemented by the Knowledge and Data Engineering Group of Trinity College, Dublin and the Cognitive Science Section of the University of Graz. Over five years, researchers in these universities designed a personalized learning process based on computer-adaptive principles. In one of their case studies, Conlan et al. (2006) chose a mechanics of physics course to test its prototype, and the adaptive ability of the ITS model was based on four KST phases:

1. *Pretest.* A framework for each student's knowledge state is built using the pretest, which provides a shortlist of problems that each student can do or is ready to learn
2. *Dynamic personalization.* A series of online modules are presented to the learner based on the topics they are capable of mastering, according to the pretest. Those topics that were already in the learner's knowledge state are skipped.
3. *Dynamic modeling.* As the student proceeds through the modules and demonstrates mastery utilizing the course content materials, the modeling tool maps out the progress of each student.
4. *Learner choice.* When all prerequisite material is learned, students can choose additional content for the online learning space to expand the scope of the course.

The second case study presented by Conlan et al. (2006) involves personalization using a program called iClass, an attempt to support a flexible, learner-centered approach. This pedagogical method seeks to facilitate the empowerment of students and teachers while allowing various processes to control the boundaries of adaptation (Turker et al., 2006). A marked difference from the first case study was the ability to determine the students' levels of confidence. After every question, the confidence degree was solicited, which allowed researchers to analyze more accurately the true knowledge state of each student and demonstrated the evolution of KST by eliminating the guesswork and reading the perception of every student (Conlan et al., 2006). What further set the iClass apart from the first case study was the Selector and LO Generator, two key services for facilitating personalized eLearning experiences (Turker et al., 2006). The two-pronged approach of the iClass process is described more adequately in the research of Conlan et al. (2006):

1. The Selector can formulate Personalized Learning Paths, which adapted concepts and learning activities to the current knowledge state of each student, based on their goals and preferences.
2. The LO Generator is responsible for selecting and assembling appropriate learning objects from the content pool.

The primary advancement of the research is the separation of the assessment from the personalization process. Whereas the landmark research of Hockemeyer et al. (1997) typically tied together assessment and personalization, its separation in the iClass case study allows for different, more effective pedagogical strategies to be used for diverse learners while still maintaining similar expectations of mastery (Conlan et al., 2006). In addition to KST, Adaptive Control of Thought-Rational (ACT-R) is another theory that supports the interactions of humans with technology to provide a rich, rigorous educational environment (Anderson, 1993).

Adaptive Control of Thought-Rational

ACT-R is the brainchild of John R. Anderson, a cognitive scientist from Carnegie Melon University with an interest in cognitive architectures and ITS models. His research focused on the application of cognitive psychology to education. Within their studies, Ritter et al. (2007) attempted to predict the educational understanding of students as well as determine what activities and experiences help them achieve curricular goals. Their research was the culmination of 25 years of work attempting to understand mathematics cognition. With over 35 million observations of 7,000 students, Ritter et al. (2007) were able to determine which factors affect learning and the overall effectiveness of individual tasks and hints, which resulted in the identification of key learning experiences to contribute to student learning of mathematics. They deemed this process a cognitive model, and the utilization of a cognitive model within an ITS is called a cognitive tutor. The landmark research and subsequent applications of ACT-R modeled higher-level cognition, but by the standards of human-computer interaction (HCI), it was deemed to be flawed (Anderson, 1993; Anderson et al., 1995; Anderson et al., 1997). During Anderson's early research, technology had not yet caught up to the theory of ACT-R, but the development of cognitive tutors helped to bridge the gap.

Like the KST, ACT-R seeks to assess current knowledge and individualize instruction, providing immediate metacognitive feedback to students to help them acquire curricular skills (Roll et al., 2011). The benefits of a personalized model of education can be immense, as students utilizing various forms of computer-assisted-instruction (CAI) experienced increased engagement, motivation, and learning within a safe, non-competitive environment (Davidovic et al., 2003). However, there are various ways in which students can seek to find backchannels around the system. For example, the research of Roll et al. (2011) cautioned against students utilizing executive help-seeking to quickly find an answer. A common strategy of cognitive tutors is to provide supplemental hints to students to facilitate a process by which they can get a minimal amount of help while still receiving necessary support. The "bottom-level" hint is the last hint given and typically eliminates various higher-order thought processes (Baker et al., 2008, p. 301). Students who need the most help often make the poorest decisions regarding their decision to click through hints, and although there have been positive attempts at improving students' help-seeking behavior, gaming the system is still a common misuse of ITS models (Roll et al., 2007).

To combat the ability of students to use strategies to circumvent the algorithms within cognitive tutoring models, Baker et al. (2008) researched ways that they could determine when students were gaming the system. Their results were promising, as their machine-learned Latent Response Model (LRM) was able to accurately detect and make predictions regarding which students would attempt to game the system (Baker et al., 2008). Like any form of pedagogical instruction, a cognitive tutor has its costs and benefits. Although gaming the system does result in disengagement from the topic and decreased learning, it is important to remain focused on the overall goal. Personalized learning does have the capacity to transform the way learners consume information, and it is important to address deficiencies as they arise by seeking to both identify when the behavior occurs and address *why* it occurs (Baker et al., 2008). Both KST and ACT-R were instrumental in developing the plethora of ITS models that have been used across countless districts within the United

States. Among those ITS models, some have proven to demonstrate a higher likelihood of success, paving the way throughout the past decades as many school districts supplemented instruction with digital curricula.

PLATO Learning

When discussing the history behind ITS models, it is necessary to begin with Programmed Logic for Automatic Teaching Operations (PLATO). Although its interface, at least initially, led to a negative attitude toward its use, there were several successes (Long, 2018). For example, PLATO implemented one of the original online message boards, which helped students become engaged with the material, arguably increasing retention levels among many online courses in various content areas (Smith & Sherwood, 1976). Ultimately, the end goal for many companies is to generate revenue, and PLATO Learning sold its rights and underwent various changes, and it is now marketed under the name Edmentum (McLeod, 2017). PLATO Learning established a benchmark for future software companies to create and market their products in the hopes of engaging students in meaningful ways.

Carnegie Learning's Cognitive Tutor

The next major step forward was taken with Carnegie Learning's Cognitive Tutor. Although there had been improvements that increased students' engagement with the interface of the ITS, Carnegie Learning began to focus on the concepts of diversity and differentiated learning (Koedinger et al., 2000). In this way, Carnegie Learning attempted to push into high-poverty areas, and the subsequent research demonstrated a high number of successes. For example, students taking Algebra I on the Cognitive Tutor program performed 85% better on complex mathematical problem solving, and the benefits showed were equivalent for both White European and African American students (Koedinger et al., 2000).

Perhaps the biggest improvement and groundbreaking aspect of the ITS model was its ability to help students improve their metacognition skills (Aleven & Koedinger, 2002). This piece allowed students to stretch themselves, which helped high-achieving students increase their knowledge while also closing the pervasive achievement gap in mathematics by allowing the opportunity for students who were behind grade level catch up to their peers.

Building Blocks Software

As much as Carnegie Learning may have improved the interface for its users, Building Blocks Software created a much more “fun” experience for its users. Initially funded by the National Science Foundation and later acquired by McGraw-Hill, the purpose was to inspire students, especially those at risk for later school failure, to develop a foundation of informal mathematical knowledge (Clements & Sarama, 2007). In other words, the Building Blocks software took differentiation one step further for underrepresented groups of students because the focus was early education. Rather than wait until there was a major issue at the secondary level, Building Blocks attempted to remediate as early as possible. To accomplish this goal, the program needed to include more than simply content knowledge. Instead, its software attempted to build on the interests of students, developing their competencies by creating a personalized form of instruction (Sarama & Clements, 2004). There was a great deal of room for improvement, however, as critics pointed to its utilization of games to “trick” students into completing rote mathematical problems (Clements & Sarama, 2011). With these improvements in mind, one of the most popular current ITS models is known as Assessment and Learning in Knowledge Spaces (ALEKS)

ALEKS

With the goal of addressing differing achievement levels of underrepresented groups, ALEKS sought to focus on mastery learning to remediate the mathematical skills of students to decrease anxiety and improve attitude (Taylor, 2008). Such an approach led to a great deal of success, especially at the collegiate level. For example, it is a common issue among universities that black and Latinx students lag their White peers in both standardized test scores and mathematics course grades (Fang et al., 2018). Although far from conclusive results, Hu et al. (2008) conducted a ten-year longitudinal study that determined course grades for African American students in a lecture format were significantly lower than their White counterparts. Interestingly, the same gap in achievement did not exist in the online course utilizing ALEKS; additionally, Hu et al. (2008) found that African American students in the online course-maintained grades that were significantly higher than those in the lecture-based format. ALEKS indicated the immense promise that ITS models offer to schools looking to narrow the gaps that greatly impact both secondary and post-secondary education. As much potential as they offer, an online curriculum cannot replace the instruction within the classroom. Certain character traits impact the long-term success of students, such as grit, defined as the combination of hard work and resiliency that helps students achieve at high levels within the educational environment (Sanguras, 2017). Such qualities are best learned through face-to-face interaction, which Summit Learning cultivates through its personalized learning experiences and opportunities for mentoring.

Summit Learning

To progress, the weaknesses of previous cognitive tutoring models and Intelligent Tutoring Systems must be taken into consideration. In this manner, Summit Learning hoped to ensure that students were able to demonstrate proficiency in four different outcomes: cognitive skills, content knowledge, habits of success, and sense of purpose (Summit Public Schools, 2017). Previous approaches only addressed the first two outcomes, as interaction with a content area was on a primary focus for remediation or progression through coursework. Summit Learning integrated two more outcomes because they believed that understanding one's strengths and weaknesses and feeling an integrated connection to their work were invaluable. One of the tenets of the ITS model is to encourage self-efficacy among students, as it has the potential to enhance or impair performance (Bandura, 1989). Summit Learning does not simply utilize a computer program to create such a process for students. Instead, the ITS model is interwoven with opportunities for students to interact with both mentors and subject-area teachers to empower them to make decisions about when and how to learn (Summit Public Schools, 2017). Such a distinction is crucial, as people differ in how they develop their efficacy, and offering varying levels of choice for students breaks the cycle of rigidity that has existed within our current structure of public education (Bandura, 2006).

An important distinction to make is that the progressive approach to education by schools that have adopted the SLP is not above reproach. There have been issues with student retention, gaming the system, and communities have been frustrated with the lack of results (Wilka & Cohen, 2013). Despite these challenges, however, the SLP is attempting to address gaps of success and access that have long plagued underrepresented groups at both the secondary and post-secondary levels (Leach & Williams, 2007). By creating a more inclusive program that focuses on both the cognitive and affective domains of learning, schools can use technology to address gaps of understanding while also inspiring students to realize their potential. Regardless of the potential of technology or the ability to target a student's current knowledge state, the ultimate success falls on building leaders to put adequate supports in place that catalyze change for all stakeholders in the educational environment.

Leading the Change

There is not a question that individuals can have a large impact on improving mathematics achievement for students. Especially in urban districts, teachers have a remarkable ability to positively affect change for the 20-200 students under their purview, depending on the age level they teach. Unfortunately, the vast difference between teachers, even in the same content area within the same building, can create pockets of students who perform below grade level. Moreover, when comparing the experience level, licensure exam score, value-added estimates of effectiveness, or any other measure of teacher quality, high poverty areas have pronounced gaps, especially in the areas of mathematics (Goldhaber et al., 2015; McGee et al., 2016). As schools turn toward technological tools to help bridge the gap, teachers alone cannot facilitate the paradigm shift. Instead, schools need strong leadership that can provide one-to-one support and deployment or re-deployment of the best teachers to teach underrepresented groups of students (Demie, 2015). Further, to shepherd in change for a district program, the implicit biases that exist within social institutions must also be considered. The work of Holroyd et al. (2017) demonstrated that implicit biases are common, unavoidable, and a product of our involuntary cognition, which contributes to a pattern of discriminatory behavior. As teachers and building leaders seek to implement change to improve achievement levels, they must be cognizant of how preconceived notions can bridge personal and systemic prejudice (Payne et al., 2017). Unfortunately, if left unchecked, this form of discrimination can be more harmful, as it is often unintentional, unendorsed, and ultimately perpetrated without awareness (Holroyd et al., 2017).

School leaders may be a potential solution to the inequity that plagues our current system, but exactly what type of leadership styles will prove effective when support reforms that utilize technological tools? DuFour and Marzano (2009) determined that especially at the high school level, schools do not need instructional leaders; instead, they need learning leaders who focus on data to gauge learning. While various forms of servant leadership do have their advantages, it is not effective when implementing new teaching strategies. Instead, servant leadership is most effective when oriented toward topics like community building and active listening (Insley et al., 2016). Increasingly, schools are realizing that it is not realistic to expect that all students can learn the same material at the same time, and constructive leadership theorists have posited students do not learn on demand (Cunningham et al., 2019). They need lessons adapted and adjusted in real-time to meet the evolving, dynamic needs of students (Brooks & Brooks, 1999). As such, data-driven and servant leadership ultimately will not prove effective when attempting to support school-wide reforms that utilize technological strategies to aid personalized learning. Returning to the Coleman Report (1966), there are two lasting conclusions that should follow any major shift in pedagogy, especially if it seeks to address an achievement gap: the most influential factor on student achievement is the community and a school's financial resources are not the end-all of any successful initiative. For this reason, those in positions of leadership should consider two theories that can intertwine to incorporate a new pedagogical model while also bridging the gap between school staff and community members who may initially be distrustful of reform: transformational leadership and instructional leadership.

Transformational Leadership Theory

Taking pieces from other theories in educational leadership, transformational leadership utilizes qualities to motivate and sustain change. Traditionally, work on leadership by Bennis (1959) showed that when the subordinate could realize their own goals without the need for punishment, a problem-solving organization could function more competently. Further, creating moral imperative and intrinsic motivation for teachers to evoke change are hallmarks of Sergiovanni's (1992) seminal studies that challenged traditional approaches to leadership. By fostering the ability of teachers to think critically while being supported emotionally, transformational leaders can stimulate the positive student outcomes they desire (Boberg & Bourgeois, 2016). At the source, it seems as if transformational leadership is infallible; surely a mix of the best pieces of all leadership styles is effective all the time. In his critical analysis, Berkovich (2016) posits that such a mix of characteristics makes it impossible to test and therefore cannot be verifiably implemented within any school reform. For this reason, it may be time to disregard transformational, for if it cannot be tested or replicated, then it cannot be a theory. Responding to such criticism, Lynch (2016) does acknowledge some of the limitations and states that "since transformational leadership is informed by all of these various types of leadership, it's always a good idea for leaders to learn more about these other styles." Put simply, a transformational leader must be at least knowledgeable about different leadership styles to utilize its features for student benefit. Moreover, transformational leadership supersedes other theories because it does not take a singular view on one aspect or another; instead, it takes a broad view and uses those as a driving force to meet the goal of the school (Lynch, 2016). As with any instructional reform, approval from stakeholders and buy-in from teachers is vital in implementing the technological tools that allow personalized learning to be effective. Without administrators grounded in theories of leadership, there will not be guidance, follow-through, or reflections, and thus student achievement will not experience sustained growth.

Modeling the Way

In any organization, workers will respond to the actions of management. By following existing rules, procedures, and norms, leaders can only operate in a transactional way (Bass & Avolio, 1993). Such an approach may be effective for some, but it does not inspire change among all employees because they are not motivated intrinsically. Instead, the leader needs to model appropriate self-leadership behavior which is more likely to be adopted by the employees under supervision (Pierce & Sims, 2002). By modeling behaviors, one wishes to see within the organization, there can be cultural shifts that meet the needs and desires of leaders. When seeking to alter culture, there is a stark difference between managers and leaders. Whereas managers tend to adopt a transactional style to manipulate short-term behaviors, leaders are more inclined to be creative, inspiring, and transformational in their behavior and outlook (Burns, 1978; Zaleznik, 1992). As schools seek to support the holistic well-being of their students and staff, leaders who can model ethical and moral behavior are more likely to support employees who are motivated, innovative, and can balance workplace challenges (Schuckert et al., 2018). In tandem with modeling, there needs to be a shared vision among leaders and staff members to create an environment that can sustain a pedagogical transformation.

Inspiring a Shared Vision

Often, meaningful alterations to the workings of an organization take time; often it is the frustration with the inability to be immediate that wears on group members.

Transformational leaders can change organizational culture by first understanding it and then articulating a clear vision for the future by eliciting a sense of purpose through common goals (Bass, 1985). Such a transition is more democratic and requires a leader to clearly communicate expectations to the group and demonstrate personal commitment. Being able to inspire confidence is crucial, and Burns (1978) discussed the importance of transformational leaders to have superb communication skills. To shift the direction within a school, there is a fine line when utilizing power and authority to convey a message. Further, supporting a shared vision requires an effective leader to be positive and patient, yet be unrelenting in the consistency for high expectations. In his analysis of what makes a leader transformational, Burnes (2009) posits that such leaders can use the sheer force of their personality to motivate followers to identify with the leader’s vision while putting the needs of the group before one’s interests. After creating and sustaining an agreed-upon vision, transformational leadership theory next shifts to the importance of action.

Enabling Others to Act

Properly supporting the development of a personalized learning environment requires that school leaders must be able to delegate effectively. Recognizing that a single administrator is unlikely to be a content expert for every department or grade level, it is important to create a cohesive team that can function well. Within transformational leadership theory, administrators must create a culture that is receptive to the team members selected not by their experience or formal leadership roles but rather their content and pedagogical expertise (Smith et al., 2017). A common failure with this strategy is to approach change using a “divide and conquer” mentality. Especially with technology, many veteran teachers may fear change because of their inexperience with such tools. To address these feelings, effective leaders support resiliency by involving teachers in the decision-making process and operate only when there is a consensus that meets an agreed-upon vision (Usdin, 2014). If utilized effectively, the transformational leadership style can help to facilitate personalized learning on a large scale by considering the strengths of each group member.

Challenging the Process

Expecting all members within an organization to be on board with a culture-challenging initiative is simply unrealistic. Instead, successful leaders welcome healthy discussion and debate while encouraging individuals to strive toward an innate interest by setting their own goals. Bono and Judge (2017) opined that transformational leadership is linked to self-concordance at work, where followers viewed their work as more important, more self-congruent, and job attitudes and performance were positive. Being able to stimulate the intellectual development of workers within an organization depends on the interaction between two characteristics: autonomy and self-efficacy. Den Hartog and Belschak (2012) posited that there are positive effects of transformational leadership, but there is a three-way interaction among those effects. In situations where there are high levels of autonomy, there is a positive relationship between transformational leadership styles and individuals with high self-efficacy. On the other hand, in situations with low levels of autonomy, there is a positive relationship between transformational leadership styles and low self-efficacy. In other words, transformational leadership is only as effective as the levels of self-efficacy within the organizational structure, as Afsar and Masood (2017) observed that creative self-efficacy mediates the interaction. If transformational leadership theory cannot affect wide-scale change within an organization, another theory must be able to support the self-efficacy of teachers, specifically in curriculum and instruction.

Instructional Leadership Theory

To ensure that learning environments within a building are effective at ensuring every student can be successful, a principal must wear many hats. Marks and Printy (2003) opined that instructional leadership matters to enhancing the quality of teaching and student performance. Although having a principal who uses strategies grounded in instructional leadership is a start, it cannot be the only factor when raising achievement levels. Hattie (2012) posited the following characteristics were integral in shaping the direction of a building:

> Accomplishing the maximum impact on student learning depends on teams of teachers working together, with excellent leaders or coaches, agreeing on worthwhile outcomes, setting high expectations, knowing the students' starting and desired success in learning, seeking evidence continually about their impact on all students, modifying their teaching in light of this evaluation, and joining in the success of truly making a difference to student outcomes (p. 37).

Incorporating each of these characteristics into daily instruction and supervision is nearly impossible without the utilization of technology. As software programs can more accurately measure student knowledge, apply an interface that is efficient for both students and teachers, and provide immediate feedback for remediation and application, leaders can gauge the effectiveness of instruction (Kallick & Zmuda, 2016). Instructional leadership theory can increase levels of achievement for students, but successful application within a school requires a more structured approach. To accomplish such a goal, the Center for Educational Leadership (2019) uses the following five beliefs to drive all work

- The *focus* of instructional leadership must always be focused on learning. Both students and adults are a part of the continuous improvement process through which all learning is measured. Although there may be a variety of instructional practices utilized, ultimately data will drive the effectiveness of each strategy, with time allocated for reflection, revision, and re-implementation.
- There must exist a *leadership team* that acts as the caretakers for instructional leadership. This team may include a variety of staff members around the building, but the principal is the ultimate overseer of all actions originating from the team.
- A culture of *reflective practice* must be built within all professional development opportunities. Staff needs to feel supported in their quest to take intelligent risks to advance the effectiveness of their instructional strategies.
- There must exist a culture of inclusivity and *equity*. The leadership team must only implement policies, procedures, and programs that function to address the cultural, linguistic, socioeconomic, and diversity in learning that exists within the larger community.
- The effective *allocation of resources* must always be analyzed, especially when changing building culture and environments.

To explore the potential effects gleaned, instructional leadership was used as a lens for the examination and implementation of the five core beliefs: focus, leadership team, reflective practice, equity, and allocation of resources.

Focus

When determining the most effective leadership theories to apply in practice within a school district, one must consider two relevant questions. First, what type of program, initiative, or reform is being applied within the organization? Second, what is the primary focus of the organization? In the context of the first question, there are unique challenges that school leaders face when attempting to incorporate technology to ensure learning can be personalized. Especially when retraining teachers in pedagogical practices, instructional leadership hinges on the following essential functions: constructing and selling an instructional vision, building norms of trust and collaboration, supporting teacher development, and monitoring instruction (Purkey & Smith, 1983; Spillane et al., 2001). Further, the success of a new program needs to be judged on the data gathered, as this process is much more objective than anecdotal reports.

To answer the question, the instructional needs of the students must be the primary focus of an educational institution. To support the curriculum within the building, instructional leaders support positive activities among teachers by modeling effective strategies, experiencing life in the classroom, and celebrating high expectations (Hunzicker, 2018). Further, there must be time for teachers to evaluate their practices and reflect on the relationship between their instructional strategies and student achievement. Darling-Hammond (2003) analyzed trends in teacher attrition as they related to the achievement levels of students. Two decades of data demonstrated that the two most powerful factors that can contribute to the achievement levels of students are the leadership abilities of the principal and the effectiveness of the teacher. These factors are especially true in urban schools, where teacher and administrator turnover are 50% higher (Darling-Hammond, 2003). Moreover, if schools hope to address the growing disparity in achievement for underserved populations, they need principals who are well-versed in instructional leadership strategies, as Darling-Hammond et al. (2005) determined these individuals are more likely to be competent in cultivating a shared vision and practice, leading instructional improvement, developing organizational capacity, and managing change. Further, because one of the largest issues in the urban core is administrative turnover, principals who demonstrate proficiency in instructional leadership are more likely to have positive attitudes and stay in the job, despite working in more challenging urban environments. For this reason, it is crucial to have a well-defined, student-centered focus if one hopes to build instructional leadership capacity. Thus, schools transitioning to a personalized learning environment and are taking steps to address the achievement gap must have a leader dedicated to ensuring the instructional strategies being used make a difference in student outcomes (Day et al., 2016). If having an agreed-upon focus that meets the instructional needs of all students is the car that moves achievement forward, an effective leadership team acts as the driver.

Leadership Team

Instructional leadership does not exist in a vacuum and cannot be dictated by a leader alone. Instead, building administrators must view the art of learning through three crucial themes: content area expertise, pedagogical principles, and teaching processes (Sergiovanni & Starratt, 2002). To support this triad of characteristics, administrators must develop a building-wide culture that cultivates teacher leaders. The most common vehicle for this process is through a professional learning community (PLC), as it can help teachers focus on learning rather than teaching, work collaboratively, and hold themselves accountable for results (DuFour, 2004). Stoll et al. (2006) conducted a review of the literature over PLCs and realized their potential to address the achievement gap occurred through building leadership capacity. Their research dictated that capacity is a complex blend of motivation, skill, positive learning, organizational conditions and culture, and infrastructure of support. If these characteristics are put together, educational reforms are much more likely to be sustained over time.

Unfortunately, one of the most common issues with schools is their inability to utilize PLCs in the correct way (DuFour and Eaker, 2009). Without a solid foundation of continuous improvement within a school, the leadership team cannot harness the collaborative power of the PLC. To ensure that a school has created an effective PLC, there are eight characteristics of successful implementation (Vescio et al., 2008):

1. Shared mission, vision, values, and goals
2. Collaboration that focuses on learning
3. Collective inquiry
4. Teacher authority
5. Action orientation and experimentation
6. Commitment to continuous improvement
7. Results orientation

Although establishing a culture that utilizes each of these characteristics may seem difficult, instructional leaders understand how crucial it is to support the tenets on which PLCs were originally built. After all, multiple studies have shown that there is a positive association between teachers' active participation in PLCs and student achievement, especially for traditionally underserved populations (Berry et al., 2005; Bolam et al., 2005; Louis & Marks, 1998; Supovitz & Christman, 2003). In order to develop a team of leaders among both administration and teaching staff, principals must effectively and efficiently utilize professional development.

Public education operates out of a limited resources environment. There is never enough time or money to accomplish everything that needs to be done to provide an equitable education for all students. As a result, principals need to engage in purposeful, job-embedded professional development (JEPD). Croft, Coggshall, Dolan, and Powers (2010) define JEPD as professional development within schools focused on quality instruction and student achievement. Moreover, it occurs during the workday and in the workplace, is closely connected to the actual work of teachers, is designed to improve instruction, is centered on the academic needs of the school, and is directly related to the agreed-upon goals set out for students. Ensuring that staff members have access to relevant, timely, and structured professional development is integral when attempted to create a leadership team that acts in the best interests of students. Too often, professional development is generalized and impersonal; although it may check a few mandated boxes at the district level, such professional development wastes the few resources that are afforded to schools. Instructional leaders, on the other hand, can utilize JEPD to create sustained professional development that leads to improved student achievement (Althauser, 2015).

Reflective Practice

In any occupation, and especially for educators, workers must have the opportunity and ability to analyze their work. Being a reflective practitioner requires the ability to reflect on one’s professional actions to engage in the continuous learning process while paying attention to the values and theories that inform everyday interactions (Schön, 2017). Instructional leaders recognize the importance of building adequate time for teachers to reflect on their pedagogical and content-area skills. Moreover, they must avoid the traps that plague schools that spend resources designing the curriculum but pay little attention to what teachers teach and even less to what students learn (Marzano 2003). More than any other skill, reflective practice among teachers takes a great deal of coaching; despite this initial drain on resources, there are long-term gains.

Especially in urban schools, there is vast turnover among administration both at the building and district levels (Bartanen et al., 2019). As a result, there is often a wait-and-see approach among teachers; why should they put in so much effort if they are going to have a new leader that attempts to integrate new ideas? Instructional leadership theory discards the series of rapid changes in the school and instead focuses on the facilitation of a growth mindset for teachers. Reflective practice through instructional leadership is a vital piece of raising academic achievement, supporting the self-efficacy of teachers, and ensuring the fidelity of instructional programs (Bandura, 1977; Donohoo et al., 2018; Newmann et al., 2001; Valenti, 2010). More than any other purpose, however, reflective practice helps support the other core areas of instructional leadership theory. Not only does it create the ability for teachers to determine if they are actively engaged in the focus of student learning as defined by the building culture, but it also supports the work of the PLC, as teachers are more likely to utilize data to make informed decisions about their students. From an instructional leadership standpoint, it is simply not feasible to coach all teachers every moment of the day. Instead, cultivating reflective practice helps to increase achievement, critical thinking, and self-efficacy by teachers' willingness to openly analyze their practices. Because a large part of effective decision-making is based on data, instructional leaders should also be aware of the inequity that exists within their current building culture.

Equity

One of the most important duties of a principal is to ensure that every student can succeed. Specifically, instruction must be viewed through a lens that permits social justice to be the primary focus. According to Cambron-McCabe and McCarthy(2005), social justice in the educational administration field "emphasizes moral values, justice, respect, care, and equity; always in the forefront is a consciousness about the impact of race, class, gender, sexual orientation, and disability on schools and students' learning (p. 202). Creating such an environment means that instructional leaders must be able to identify which characteristics of the school culture need to change and what method would be most effective to change them. If leaders seek to maintain the current status quo, this marginalizes both students and their support system and silences any attempt to acknowledge their needs (Skerrett et al., 2018). Further, instructional leadership theory suggests that to increase achievement levels for underrepresented groups of students, principals need to engage in moral dialogue that supports the development of strong relationships, challenges existing practices, and grounds all changes in a belief of social justice (Shields, 2004).

To accomplish these lofty goals, leaders must provide meaningful professional development opportunities that are centered on principles of equity. Although there have been many approaches that have proven beneficial to addressing social injustices that occur within a school, the more successful ones have focused on a combination of building relationships, facilitating engaging and meaningful instruction, and holding every student to high expectations. For example, Skerrett et al. (2018) were the first researchers to provide a foundation for urban teachers' needs for professional development that promotes equitable stances and practices, and they found six common characteristics among successful professional development.

- Focused on specific aspects of curriculum, teaching, and learning that teachers themselves identified as areas in which they needed and wanted to grow
- Content offered was recognized by teachers as grounded in evidence-based research and experts' practice and facilitated by professionals who were themselves recognized by teachers as experts in that content area.
- Teachers' professional knowledge and expertise were valued with interchangeable roles for teachers as both learners and teachers.
- Sustained over time in which teachers deepened their knowledge and skills in an area, but also developed increasingly complex questions and ambitious goals for their learning in an area of professional practice.
- Intimate, allowing for building personal and professional relationships with those who teachers worked with most closely at their schools. Teachers viewed these intimate relationships as creating conditions for collaboration and shared learning around curriculum and teaching despite differences in teachers' ideologies and practices.
- Supported by political agents with institutional power such as school districts, principals, and literacy coaches. In some cases, this institutional support provided material resources to teachers to pursue the learning they most desired, which was how to enact a social justice focused educational agenda.

More than any other aspect of a principal's job, ensuring that students are afforded equitable opportunities must be at the forefront of instructional leadership. Through this lens, the focus of leadership teams and reflective practitioners can help provide a more socially just education.

Allocation of Resources

As previously mentioned, public schools typically operate within a limited resources environment. Especially in low-income areas, there exist drastically different learning opportunities. These include less access to well-qualified teachers, lower quality curriculum, and higher-class sizes, all of which are related to differences in student achievement (Darling-Hammond, 2004). Within such areas, school leaders must be creative as they develop effective and efficient systems that meet the needs of their schools. One way to do this involves the way a school district is organized. Although there are laws that restrict some of the financial resources that are received and allocated, schools in urban areas have experienced success in the decentralization of resource allocation decisions (Okpala et al., 2000). By providing individual schools with the economic autonomy they need, principals can more effectively act as instructional leaders by supporting programs.

With limited exceptions, no effective program comes free of cost. Whether it includes monetary resources, time, or personnel, the principal must find a way to allocate funds in a way that supports the mission and vision of the school. Additionally, these resources must be used to support mindful interventions for students and professional development for teachers (Zenner et al., 2014). Being able to connect every action back to a common goal while providing both a location for teachers to meet and the time for them to grow as educators is crucial to ensure building-wide success. Often, to ensure that resources are deployed equitably, particularly in areas where resources are diminishing, effective instructional leaders use data to make strategic decisions (Rimmer, 2016). Although last to be mentioned, effective resource allocation is the glue that allows building focus, leadership teams, reflective practice, and equity to work together cohesively. Without the effective utilization of resources, the organizational change would be too disjointed and prohibitive for teachers.

In conclusion, effective leaders can harness the abilities of teachers by utilizing both transformational and instructional leadership theories. First, the transformational leadership theory is needed to reframe the lens through which educational strategies are perceived by staff members. This requires an agreed-upon vision and actions by a leader that utilizes positive relationship building, a democratic approach, and the ability to cultivate intrinsic motivation through building leadership capacity. After these qualities are supported, a principal can turn to instructional leadership theory to facilitate curricular changes with the building. There is no question that teacher quality has the most impact on student achievement, especially among underrepresented groups of students and those in high poverty areas (Sanders et al., 1997). Thus, to help staff members improve their quality and focus their efforts in a meaningful way, principals must use transformational and instructional leadership theories in tandem to support the increasingly diverse needs of students.

CHAPTER 3

METHODOLOGY

There has been a consistent attempt through the years to increase achievement levels in mathematics for all students, but especially for those in underrepresented groups who fail at inequitable rates (Crouzevialle & Darnon, 2019). The problem of mathematics achievement has been pervasive, despite the reforms and technological advances that have occurred. The purpose of this study was to determine if an intelligent tutoring software, called the Summit Learning Platform (SLP), had a positive impact on mathematics achievement and, in particular, how achievement levels vary by student demographic.

This quasi-experimental study investigated the SLP and its potential association with mathematics achievement for students in grades nine through eleven in a suburban school setting by providing answers to the following research questions:

1. Is there a significant difference in NWEA-MAP mathematics scores when comparing student pretest and posttest results among students using the SLP?
2. How do mean posttest mathematics scores differ among students by race/ethnicity and income status when using the SLP, as measured on the NWEA-MAP? Specifically, do scores differ between Black, Latinx, Multi-Ethnic and White students? Are scores different among Free- and Reduced-Lunch Qualifying (FRLQ) students and non-FRLQ students?
3. Is there a significant difference in ACT mathematics scores when comparing 11th grade students who received traditional instruction and students who received instruction using the SLP?

4. Is there a significant difference in pre-ACT mathematics scores when comparing 10th grade students who received traditional instruction and students who received instruction using the SLP?
5. How do mean posttest mathematics scores differ among students by race/ethnicity and income status when using the SLP, as measured on the pre-ACT? Specifically, do scores differ between Black, Latinx, Multi-Ethnic and White students? Are scores different among FRLQ students and non-FRLQ students?

The SLP is a web-based platform that utilizes an online learning system to deliver curriculum while applying an artificially intelligent adaptive learning software to assess students' current state of knowledge. This chapter describes the methodology for the research and includes an overview of the location and participants, instruments used for data collection, and statistical procedures to analyze the data. Described first is an explanation of how the SLP functions differently when compared to a traditional classroom environment.

Summit Learning Platform

The intervention studied is called the SLP, a type of adaptive learning software that delivers the mathematics curriculum and instruction. Although instruction is delivered differently with the SLP when compared to what is deemed traditional instruction, students are still required to demonstrate proficiency over the same learning objectives. One of the main differences when comparing the philosophy behind the SLP and the traditional high school setting is a focus on multiple domains of learning. With the SLP, the affective domain is of equal focus for the delivery of content. To support the student holistically, the goal of the SLP and the schools that implement its principles is to have students demonstrate proficiency in the following four outcomes:

Cognitive Skills

At the ACE Leadership Academy for Innovation, the treatment group, students are provided with multiple opportunities to demonstrate their mastery. Further, these skills are learned by providing students with experiences that are inquiry-based, authentic, and active, as such strategies require higher-order thinking skills (Barron & Darling-Hammond, 2008). The approach that combines multiple opportunities to practice the same skills while requiring proficiency in cognitive skills generates more resilient students, a characteristic of individuals who are successful in both college and their career (Fadel et al., 2015). Noguera (2003) studied how resiliency and self-efficacy impact a student's ability to be successful in their educational endeavors. Especially among black students, he found that the strongest predictors of success were self-efficacy and ethnic identity, which directly related to student's active resiliency. Developing a student's ability to think cognitively is important to post-secondary success and should precede the next outcome- knowledge in a subject area.

Content Knowledge

Although many aspects of public education have changed over the last few decades, the overall goal is still the same: Students need to master a set number of skills to contribute to society in a meaningful way (Dewey, 1916). The skills deemed appropriate have transformed, as have pedagogical practices, but to be effective, the curriculum must be guided by a clear set of content standards grounded in a shared vision of teaching and learning (Latif, 2014). There is no one-size-fits-all approach to ensuring that all students gain the knowledge necessary but allowing them the flexibility to take an assessment at varying points in time and exploring topics based on their interests are effective ways to make sure that students are realizing their potential (Rose, 2016). Weaving flexibility, autonomy, and accountability is integral to realizing Summit Learning's mission statement, so each of these characteristics is built into its online learning platform.

Habits of Success

Where the SLP program begins to differentiate from other platforms is support of qualities that help students develop the skills they need to be successful in life. Recognizing that students need to be taught in ways that validate their experiences while providing a culturally responsive education is just the first step to ensuring every student has an equitable opportunity to succeed (Dee & Penner, 2016). Further, students need the opportunity to have one-on-one mentoring each week to help set goals and reflect on progress, self-directed learning to develop self-awareness, and project-based learning to understand concepts in terms of real-world applications (Farrington et al., 2012; Stafford-Brizard, 2016). By utilizing these methods to facilitate the learning process, the SLP can help students learn and grow from their decisions to foster a sense of using knowledge to navigate their worlds, including community.

Sense of Purpose

Without a sense of purpose, students see learning within a content area as a chore and become less likely to persevere when challenged. The SLP attempts to build five critical components within students who participate in the program (Summit Public Schools, 2017):

- Self-Awareness—Students need the freedom and flexibility to explore multiple interests and the opportunity to reflect on their experiences within such exploration.
- Values—To live a fulfilled life, students must develop their own set of values and learn how to weigh options based on their values.

- Relationships—Students must learn how to foster relationships that support their values and future goals rather than seeing relationships as transactional.
- Credible path toward long-term goals—Students need to be able to communicate their goals and have a plan to reach them.
- Transition—Students need to have a plan for their next steps after high school that is aligned with their interests, skills, and passions.

In the traditional model of instruction at two of the high schools, participants of the control group, students learn content in a linear model, regardless of pre-knowledge. Instruction is teacher-centered, with direct instruction taking precedence through most content. Students at the ACE Leadership Academy, participants of the treatment group, have curriculum facilitated with the SLP. Within the study, students were placed at their knowledge state within each learning objective and proceeded through the content at their own pace until receiving a mastery learning percentage, defined by the district as 80% (New Rochelle School District, 2020). By advancing through mathematics content in such a way, receiving mentoring support from their teachers, and participating in problem-solving activities that help align learning objectives to tangible problems within the community, students in the treatment group are more likely to display the five critical components listed previously. Consequently, Damon (2008) posits that the students in this program are more likely to be persistent, resourceful, resilient, and have the capacity for healthy risk-taking. Most schools seek to support each of these four learning outcomes and have instituted various wraparound services designed to realize some level of achievement in each. This quasi-experimental study sought to quantitatively determine if there is a positive association between the utilization of the SLP and achievement in mathematics among high school students in grades nine through eleven.

Rationale for Site Selection

In the following section, an explanation is provided for the reasoning behind the location selected. Additionally, the participants of the study are described in depth, including their demographic profile. Once completed, I discuss the methodology and best way to analyze the results.

Location

Public schools hope to narrow the achievement gap by utilizing technology to support students and differentiate instruction (Macgilchrist, 2019). Although many schools utilize technology as enhancements to the curriculum, most traditional classrooms lack the consistent application of a single adaptive learning software system to personalize instruction. To determine the effectiveness of the SLP, participants for the study came from three different public high schools within one school district to provide generalizable knowledge for local school districts regarding the application of the SLP. The schools in the study are located within a single community, just outside the urban core of a large Midwestern city.

Participants

The three high schools are in close geographic proximity, serve families from the same community, and have been recently re-districted. Due to these commonalities, the schools have similar demographic profiles, as demonstrated below (New Rochelle School District, 2020):

- 30-35% diverse population, primarily African American and Latinx

- 20% FRLQ Students
- Heavy focus on college readiness, especially in science, technology, engineering, and mathematics (STEM)
- 80% of students pursue post-secondary education
- Experienced teaching workforce: Average experience 11 years, 85% with advanced degrees

Since all three schools are located within the same district, all courses have identical curriculum and teachers receive equivalent district-wide professional development, and students receive the same content within each course. While two of the high schools apply a traditional model of instruction and the other utilizes a web-based platform, all schools cover the same subject matter. In eighth grade, students are provided the choice of attending a school that utilizes a traditional model or one that utilizes the SLP, so the treatment and control samples are naturally formed without any interaction.

Intended to make inferences about all public-school students that utilize Intelligent Tutoring Systems at the secondary level, the accessible population consists of students in grades nine through eleven at each of three high schools. The sample size is approximately 2,500 students, with 2,000 students attending the traditional schools (control group) and 500 attending the ACE Leadership Academy for Innovation (treatment group). Since the ACE Leadership Academy requires that demographic characteristics be similar across all schools, there is not a need to account for any potential differences between the control and treatment groups during the statistical analysis process.

Methods

Data Collection

The data were collected from the 2018-2019 school year. All participants in the experimental group completed fall, winter, and spring benchmarks of the NWEA-MAP mathematics assessment. Additionally, students in both the experimental and control groups took the pre-ACT (10th grade) and ACT (11th grade). For each assessment, all data were stored at the district office, and administrators have access to it at any point in time. Historical data from standardized tests are stored either at the district office or on the servers operated by NWEA.

Procedure

Approval was gained from the school district before obtaining and utilizing student data. To follow federal law and maintain student privacy, all guidelines under the Family Educational Rights and Privacy Acts (FERPA) were followed with fidelity. All data sets are archived within district student information systems with administrator access, so there was not a need to directly interact with participants at any time throughout the study. Upon receiving IRB approval, administrators within district office were contacted to retrieve the necessary data points. Once written permission was granted from the Executive Director of Quality and Evaluation, the Director of Curriculum was able to provide access to archived student data scores on the NWEA-MAP, pre-ACT, and ACT for the 2018-2019 school year. Data were gathered from this school year due to the unavailability of test results in the 2019-2020 school year due to the COVID-19 pandemic. Since each student had the choice to enroll in the ACE Leadership Academy for Innovation and thus be a part of the treatment group, there was not a need to inform the participants in the study, as students were already in naturally formed control and experimental group environments. Since the treatment had already been applied to the students throughout the 2018-2019 school year, I was able to access student archival data (demographic and achievement) and execute the experiment.

Design

The study implemented a research design that utilizes both a pretest-posttest and non-equivalent groups' posttest model to compare mathematics achievement between a control and treatment group. The pretest-posttest design was utilized to compare student growth among those receiving the treatment, as measured by the NWEA-MAP mathematics assessment given multiple times throughout the year. The nonequivalent groups' posttest was applied to compare the results of students in 10th grade on the pre-ACT and students in 11th grade on the ACT between the control and experimental groups. The control group comprised of individuals receiving traditional instruction at two of the high schools, and the experimental group consisted of participants electing to attend the ACE Leadership Academy for Innovation, which used the treatment (SLP) to deliver content instruction. The treatment group consists of students who chose to attend the school delivering the treatment program, and the control group had no knowledge of the SLP and little to no connection to the participants in the treatment group. As a result, the research design was able to minimize threats to reliability and validity that typically impact most experimental designs that apply a similar structure. Finally, because students elected which high school they wanted to attend, there was not a random assignment of participants, so the design is deemed quasi-experimental.

Measures

To generalize findings for similar school districts, the following demographic information was collected using the administrative data disaggregated by school: ethnicity/race (Black, Latinx, Multi-Ethnic, and White), gender (male or female), income status (FRLQ and non-FRLQ), and grade levels (9, 10 or 11). In addition to demographic information, student achievement data were collected by analyzing mathematics performance on the NWEA-MAP, pre-ACT, and ACT. Finally, students were classified by the type of instruction received: traditional instruction versus instruction facilitated by the SLP.

NWEA-MAP

The mathematics portion of the MAP is a norm-referenced adaptive learning test created by the Northwest Evaluation Association (NWEA), a non-profit that provides assessment and growth scores for schools across the nation (2011). Utilizing Rasch Unit (RIT) scores, the achievement level of a student can be determined when compared to same-aged peers while also gauging how much was learned over a school year (NWEA, 2018). In addition to using RIT scores to measure achievement levels, the test developers of the NWEA-MAP have years of reliability and validity evidence (Thum & Hauser, 2015).

For an assessment to be deemed consistent, it must demonstrate test-retest and parallel reliability (Heale & Twycross, 2015). That is, students who take the same assessment twice or take an alternate form should score consistently at the same level, within a reasonable standard error. To demonstrate these two types of reliability, the developers of the NWEA-MAP have conducted multiple studies that utilize the Pearson *r* correlation coefficient. Estimates for test-retest and parallel forms reliability of the NWEA MAP mathematics test in Missouri yielded Pearson correlation coefficients that averaged 0.87 for students in secondary grades (NWEA, 2011). Because the minimum threshold for reliability is an *r*-value of 0.80, the NWEA results demonstrate strong reliability (Crocker & Algina, 2008). Additionally, it is also necessary to demonstrate internal consistency among test items. NWEA created a test to measure internal consistency, called the marginal reliability coefficient (NWEA, 2011). In a 2009 study, the NWEA MAP mathematics had marginal reliability coefficients ranging from 0.92 to 0.97 for students in grade nine (NWEA, 2011). Since a Cronbach's Alpha value of 0.70 or higher is deemed consistent, the NWEA-MAP met this minimum criterion (Cortina, 1993).

Lastly, it is important to distinguish if an assessment measures what it is supposed to, referred to as construct validity (Bagozzi & Phillips, 1991). In 2009, a test to determine concurrent validity for the NWEA-MAP mathematics averaged 0.84 for 9th grade students (NWEA, 2011). For an assessment to have construct validity, a Cronbach's alpha must be above is 0.70, which means that once again, the NWEA-MAP can be a deemed valid assessment for this research (Cortina, 1993; Bland & Altman, 1997).

Pre-ACT and ACT

In addition to the NWEA-MAP, which measured differences within the treatment group, the pre-ACT and ACT were essential to compare the control and treatment groups. Both the pre-ACT and ACT are norm-referenced tests that consist of four subject areas (English, Mathematics, Science, and Reading). ACT utilizes a scale to determine how far away from the target mean of the assessment a student is, theoretically demonstrating how "college-ready" students may be (Kolen & Hanson, 1989; Kolen, 1991). Because it has been utilized for over three decades, the pre-ACT and ACT have consistently communicated both reliability and validity evidence.

To demonstrate test-retest and parallel reliability, test developers have conducted multiple studies that utilize the Pearson *r* correlation coefficient. In 2011, estimates for test-retest and parallel forms reliability yielded median reliability of 0.91, as measured by the Pearson *r* (ACT, 2017). As previously stated, the minimum threshold is an *r*-value of 0.80, which implied that the results from both assessments are reliable. On the pre-ACT and ACT, internal consistency yielded a median value of 0.87 with a range of 0.84 to 0.91, utilizing a sample size of 20,000 (ACT, 2017). Since a Cronbach's Alpha value of 0.70 or higher is needed to deem an assessment has internal consistency, both the pre-ACT and ACT met this minimum requirement (Bland & Altman, 1997).

Especially when utilizing the ACT, which forecasts post-secondary achievement, the assessments should be reasonably accurate when predicting success at the post-secondary level. To determine if the pre-ACT and ACT had construct validity, Noble and Sawyer (2002) analyzed concurrent validity over each content area with multiple ACT assessments. They observed a range in *r*-value of 0.70 to 0.92, with a median value of 0.81, which provided strong evidence for construct validity. In the next section, the procedural details of the study are discussed.

Analysis

The study seeks to determine the effectiveness of the SLP, an adaptive learning assessment software, on mathematics achievement for secondary students in grades nine through eleven. I utilized a quasi-experimental design and both a pretest-posttest and posttest only methodology with a control and treatment group made up of students from three high schools within the same school district.

Independent and Dependent Variables

In the first and second research questions, the independent variable was the demographic classification of the students who attend the ACE Leadership Academy. Because the NWEA-MAP mathematics test is only given to the treatment group, only students who are in the treatment group were included. For the remaining questions in this study, the types of instruction within the school served as the independent variables. Traditional instruction is utilized in two of the high schools with a limited pedagogical application of adaptive learning technology. For following student learning at the ACE Leadership Academy for Innovation, the SLP is utilized to assess student learning and apply the necessary content for each subject area. For the purpose of following student learning at the ACE Leadership Academy, the NWEA-MAP mathematics test is given at three separate times throughout the school year. These test results were analyzed to determine growth in student mathematics achievement. Unfortunately for this study, the high schools that make up the control group do not employ the NWEA-MAP consistently, opting to only give the test to students receiving special education and those in remedial courses like pre-Algebra. However, all students within the school district take the pre-ACT in 10th grade and the ACT in 11th grade. Thus, these tests served as comparison data for students in the control and treatment groups. In the next section, the following research questions for this study are addressed, while also providing the corresponding hypotheses and rationale for statistical tests.

Research Question 1

Is there a significant difference in NWEA-MAP mathematics scores when comparing student pretest and posttest results among students using the SLP?

Research Question 2

How do mean posttest mathematics scores differ among students by race/ethnicity and income status when using the SLP, as measured on the NWEA-MAP? Specifically, do scores differ among Black, Latinx, Multi-Ethnic and White students? Are scores different between FRLQ students and non-FRLQ students?

Hypothesis 1. There is no significant difference in NWEA-MAP mathematics scores when comparing student pretest and posttest results among students using the SLP.

Hypothesis 2. There is no significant difference in mean posttest NWEA-MAP mathematics scores among students by race/ethnicity and income status when using the SLP.

Statistical Tests and Rationale. To test the first and second hypotheses, student gain scores were calculated utilizing the RIT score guidelines from NWEA-MAP. This calculation involved subtracting pretest RIT scores from the mathematics portion of the NWEA-MAP from posttest RIT scores. A single-sample paired *t*-test was used to determine if the gain score is significantly different from 0, defined as no mathematics growth among students in the treatment group, the independent variable. Finally, a mixed analysis of variance (ANOVA) was used to test the second hypothesis, where Black, Latinx, White, Multi-Ethnic, FRLQ, and non-FRLQ groups served as the independent variables and NWEA-MAP scores served as the dependent variable. The effect size can also be helpful, so a post hoc Tukey Test determined if one of the specific groups' means is different (Brillinger, 1984). Because the first two hypotheses only include students from the SLP, it is only appropriate to include students in grades nine through eleven at the ACE Leadership Academy for Innovation.

Research Question 3

Is there a significant difference in ACT mathematics scores when comparing 11th grade students who received traditional instruction and students who receive instruction using the SLP?

Research question 4

Is there a significant difference in pre-ACT mathematics scores when comparing 10th grade students who received traditional instruction and students who receive instruction using the SLP?

Hypothesis 3. There is no significant difference in ACT mathematics scores between 11th grade students who received regular instruction and students who received instruction using the SLP.

Hypothesis 4. There is no significant difference in pre-ACT mathematics score between 10th grade students who received a regular instruction and students who received instruction using the SLP.

Statistical Test and Rationale. To test the third and fourth hypotheses, a *t*-test compared the test results of 10th/11th grade students receiving traditional instruction with 10th/11th grade students who are progressing through the instruction of the Summit Learning Platform. In both statistical tests, the independent variables were the type of school a student attends and the dependent variable was the corresponding mathematics sub-score on either the pre-ACT (10th grade) or ACT (11th grade). Additionally, I ran a post hoc test, Cohen's d, to determine the effect size when comparing the performance of students who received traditional instruction to students utilizing the SLP (Cohen, 1977).

Research Question 5

How do mean posttest mathematics scores differ among students by race/ethnicity and income status when using the SLP, as measured on the pre-ACT? Specifically, do scores differ between Black, Latinx, Multi-Ethnic and White students? Are scores different between FRLQ students and non-FRLQ students?

Hypothesis 5. There is no significant difference in pre-ACT mathematics scores among students by race/ethnicity and income status when using the SLP.

Statistical test and rationale. Finally, to test the fifth hypothesis, scores on the pre-ACT were disaggregated by demographic categories (Black, Latinx, Multi-Ethnic, White, FRL, White, and non-FRL) and perform a factorial ANOVA test, where there are two treatments (SLP and non-SLP), two income statuses (FRLQ or non-FRLQ) and demographic categories, mentioned above. The demographic categories served as independent variables and the corresponding student pre-ACT scores functioned as dependent variables. A post hoc Tukey Test helped determine the potential effect size of the results. Before presenting any analyses or findings, the limitations and ethical concerns of the research must be discussed.

Limitations

The high school that employs the SLP as a vehicle for content delivery is only in its fourth year overall and first with students in grades nine through twelve. As a result, longitudinal data like graduation rate, number of remedial courses taken in college, advanced placement (AP) enrollment, or college graduation rate cannot be considered within the scope of this study. While these measures might paint a more holistic picture of student success, they are not available at this time. Students are also presented with the option of enrolling in the treatment group, creating self-selection bias. Theoretically, this could create a situation in which only high-achieving students elected to attend the control or treatment group. Finally, students can transfer from the high school that utilizes the SLP to a one of the traditional high schools (and vice versa) at the end of each school year. Students who engaged in such a practice did not qualify for the study and were removed utilizing the process of listwise deletion, as students who fit such a description had missing data points.

An additional limitation that had an impact on the ability to gather data for the 2019-2020 school year was the changes in testing that have occurred due to the COVID-19 Pandemic. Missouri has canceled all statewide testing for the 2019-2020 school year, and nationally, the ACT and pre-ACT tests have been postponed. As a result, only data from the 2018-2019 school year was utilized. This created a few issues for the study, as it impacted the sample size on some statistical tests and made it more challenging to ensure that underrepresented groups of students were accurately depicted by the available data. In particular, the sample size for the treatment group was much smaller ($n = 14$) than the control group ($n = 277$) for the ACT. As previously mentioned, the disparity in sample sizes was due to the inability to utilize test data from the 2019-2020 school year. Further, as students returned to school in the fall, they were given the opportunity to attend school virtually. Due to this factor, there were two potential problems. First, the new modality of learning acted as a large confounding variable within the study, threatening to undermine any results gleaned. Secondly, all students who selected virtual learning were placed in a separate location within the student information system. Although such an approach was helpful for both administration and staff, it meant the process to place students in their appropriate designation (control vs. treatment) was convoluted. This was yet another reason to utilize data from a previous year, and any students who were impacted by a change in learning modality were removed from the study.

Ethical Consideration

For the integrity of the study, it is important to note that student data were used from the high school and school district that employs me. As a result, various ethical considerations were addressed in this study. Specifically, all measures were taken to ensure that student privacy was protected via FERPA. Further, all markers of individual students were removed so that students could only be classified by demographic markers. Finally, before collecting any student data, IRB approval was granted for the study.

CHAPTER 4

RESULTS OF ANALYSES AND CONCLUSIONS

The purpose of this study was to determine the effectiveness of the Summit Learning Platform (SLP) on student achievement in mathematics, as measured by pre-post and between-groups measures. The traditional focus of schools on cognitive reform and the subsequent deemphasis on the affective needs of students may negatively impact student achievement in mathematics (Barieva et al., 2018). This study sought to determine if the SLP can effectively utilize a more holistic approach to education in order to better meet the needs of students. As stated in Chapter 3, there were five hypotheses tested in this study. Each was chosen to distinguish if learning was occurring within the treatment group and subsequently, if a significant amount of learning was occurring when the treatment group was compared to the control group (Summit Learning Platform vs. traditional high school instruction, respectively). Within each hypothesis test, learning was measured by performance on a norm-referenced standardized test. The null hypotheses are described below:

- *Hypothesis 1.* There is no significant difference in NWEA-MAP mathematics scores when comparing student pretest and posttest results among students using the SLP.
- *Hypothesis 2.* There is no significant difference in mean posttest NWEA-MAP mathematics scores among students by race/ethnicity and income status when using the SLP.
- *Hypothesis 3.* There is no significant difference in ACT mathematics scores between 11th grade students who received regular instruction and students who received instruction using the SLP.

- *Hypothesis 4.* There is no significant difference in pre-ACT mathematics score between 10th grade students who received a regular instruction and students who received instruction using the SLP.
- *Hypothesis 5.* There is no significant difference in pre-ACT mathematics scores among students by race/ethnicity and income status when using the SLP.

Descriptive statistics and chi square tests determined there was a similarity among schools involved in the study to discern the appropriateness of any generalizations. Next, each of the hypotheses were addressed using the statistical tests described in Chapter 3. Results from each of these tests are presented in the following sections.

Characteristics of Experimental and Control Groups

To adequately compare the results between each school, the descriptive statistics to determine if populations within the experimental and control groups are detailed. As all subject selection was done utilizing historical data, the study itself is deemed quasi-experimental. The school district was recently redistricted to account for enrollment inequities, so the demographics of each school can be considered similar. To provide a complete picture of the data, the following variables were examined: grade level, race, gender, and income status.

There are a few characteristics unique to the treatment group. In the first two years of existence, the Ace Leadership Academy for Innovation (ACE) had to restrict the number of applicants based on attendance due to space constraints. Rather than operating out of a school building, the district had to lease and repurpose office space. Although no students were denied entry into the treatment group, the amount of advertisement increased by year three, leading to a higher enrollment. For the purposes of this study, most 9th and 10th grade students are not included, as they did not have an opportunity to take standardized tests in the spring of 2020 (see Chapter 3). Although this restricts the sample size of the group, it also provides a closer correspondence between treatment and control groups based on grade level, as demonstrated in Table 4.1. A chi-square test confirmed the groups were not significantly different (p = .53).

Table 4.1

Comparison of Control/Treatment Group Participation by Grade Level (n = 2756)

Grade	Percent (%)		Frequency (n)	
	ACE	Traditional	ACE	Traditional
9th	32.59	25.57	146	590
10th	26.56	24.52	119	566
11th	18.53	24.83	83	573
12th	22.32	25.09	100	579
Total	100	100	448	2308

I next examined the treatment and control groups by gender, race, and income status. Although there is a correspondence between control and treatment groups based on gender confirmed by a chi-square test (p > .05; table 4.2), there is slight discrepancy in the correspondence between the treatment and control groups based on race (table 4.3). Of note, Asian and Indian students were not accounted for in any of the statistical tests, as these underrepresented groups did not have large enough of a sample size to be included on data reported by the Department of Elementary and Secondary Education (2019).

Finally, there appears to be a slight difference in the correspondence between the treatment and control groups based on income status, as measured by students who qualify for Free- and Reduced-Lunch (FRLQ). When comparing the treatment and control groups, there are 4% more FRLQ students in the treatment group, but a chi-square test determined that there was not a significant difference (p = .17; table 4.4).

Table 4.2

Control and Treatment Group Participation by Gender (n = 2756)

Gender	Percent (%)		Frequency (n)	
	ACE	Traditional	ACE	Traditional
Male	54	53	240	1216
Female	46	47	208	1092
Total	100	100	448	2308

Table 4.3

Control/Treatment Group Participation by Race (n = 2756)

Race	Percent (%)		Frequency (n)	
	ACE	Traditional	ACE	Traditional
Asian	3	4	12	93
Black	6	10	28	235
Latinx	10	10	44	236
Indian	1	1	3	13
Multi-Ethnic	5	6	24	127
White	75	69	336	1593
Total	100	100	448	2308

Table 4.4

Control/Treatment Group Participation by Income Status (FRLQ) (n = 2756)

Lunch Status	Percent (%)		Frequency (n)	
	ACE	Traditional	ACE	Traditional
Free	16	13	69	296
Reduced	4	3	19	76
Full Pay	80	84	360	1936
Total	100	100	448	2308

Although there is an indication of a slight differences in the demographic profile of both the control and treatment groups, there is still a significant amount of correspondence, which. As a result, it is reasonable to assume the performance of students, as measured by the NWEA-MAP, pre-ACT, and ACT should be expected to be similar, as each set of students had received comparable instruction prior to their experience in the control or treatment group. Based on the descriptive statistics and chi square tests, analyses preceded; there was no significant difference among demographic groups (White, Black, Latinx, Multi-Ethnic, and FRLQ). Statistical analyses were performed to address each of the hypothesis tests, with post hoc analysis completed as appropriate to answer the following research questions:

1. Is there a significant difference in NWEA-MAP mathematics scores when comparing student pretest and posttest results among students using the SLP?
2. How do mean posttest mathematics scores differ among students by race/ethnicity and income status when using the SLP, as measured on the NWEA-MAP? Specifically, do scores differ among Black, Latinx, Multi-Ethnic and White students? Are scores different between FRLQ students and non-FRLQ students?
3. Is there a significant difference in ACT mathematics scores when comparing 11th grade students who received traditional instruction and students who receive instruction using the SLP?
4. Is there a significant difference in pre-ACT mathematics scores when comparing 10th grade students who received traditional instruction and students who receive instruction using the SLP?
5. How do mean posttest mathematics scores differ among students by race/ethnicity and income status when using the SLP, as measured on the pre-ACT? Specifically, do scores differ between Black, Latinx, Multi-Ethnic and White students? Are scores different among Free- and Reduced-Lunch Qualifying (FRLQ) students and non-FRLQ students?

Hypothesis Testing

In hypotheses 1 and 2, the only data analyzed come from students who attend the treatment group, which utilizes the SLP. The null hypotheses are as follows:

Hypothesis 1. There is no significant difference in NWEA-MAP mathematics scores when comparing student pretest and posttest results among students using the SLP.

Hypothesis 2. There is no significant difference in mean posttest NWEA-MAP mathematics scores among students by race/ethnicity and income status when using the SLP.

Students in the treatment group exhibit a RIT score improvement of 4.36 (233.52 to 237.87) on average, or an observed value roughly 60% higher than what is expected (Table 4.5). Since students in the control group do not take the NWEA-MAP, there is no feasible way to determine if such an improvement is due to the SLP and teaching methodology or if it is simply a product of the school district. Subsequent hypotheses tests hope to address such a question, while also determining if there is any inequity among the studied demographic groups.

Table 4.5

Single Sample Paired t*-test Summary Statistics*

Paired Samples Statistics (n = 321)		
	Mean	Std. Deviation (SE)
Fall (pretest)	233.51	19.32 (1.08)
Spring (posttest)	237.87	19.89 (1.11)
		Correlation
Correlations		.924*

The single sample paired *t*-test results show there is a statistically significant difference in the mean spring mathematics Rasch Unit (RIT) score, as highlighted in table

4.6. As a result, the null hypothesis should be rejected. In addition to being statistically significant, the increase of mean test score can be interpreted further utilizing the RIT score. The mathematics student growth norms for the NWEA average 2.7 for high school students (NWEA, 2018). In other words, the average student exhibits a year of content growth if their RIT score improves by 2.7.

Table 4.6

Single Sample Paired t*-test Results*

Paired Samples Test (n = 321)								
	Paired Differences							
	Mean	Std. Dev.	SE	Lower	Upper	t	df	p
Pre/Post	4.36	7.68	.43	3.51	5.20	10.16	320	<0.001

The second hypothesis was tested using a mixed analysis of variance (ANOVA) using the SPSS General Linear Model. The mixed ANOVA demonstrates there are significant results within the demographic groups based on race and income status, as measured by Free- and Reduced-Lunch Qualifying (FRLQ) students. Because there are only two groups in the FRLQ category (students qualify or they do not), a significant p-value ($p < .001$) results in the rejection of the null hypothesis (table 4.7). In addition to FRLQ, the results from the mixed ANOVA also indicated that student race was significant at the .05 alpha level. Thus, the second null hypothesis was rejected as well.

The results indicated that there was at least one race significant in the demographic profile, and to determine which race or races were significant, and at what level, I performed a post hoc Tukey test (table 4.8). When compared to their peers in each of the other four demographic profiles in the study, Black students had a smaller increase in their performance on the mathematics portion of the NWEA-MAP. Further, Latinx students were not statistically significant at the .05 level when compared with any other group. These results dictate a trend that will be further discussed in Chapter 5; Black students experienced the least growth of any demographic group within the treatment and started with the lowest average performance on the fall NWEA assessment.

Table 4.7

Mixed Analysis of Variance Results

Between Subjects Effects				
Source	Type III Sum of Squares	df	Mean Square	Sig.
Intercept	4496840.96	1	4496840.96	.000
Race	19839.03	5	3967.81	.000*
FRLQ	6336.12	1	6336.12	.001*
Race*FRLQ	140.57	4	35.14	.994
Error	191219.66	311	614.85	

Table 4.8

Post hoc Test and Analysis

Multiple Comparisons				
Race	Race	Mean Difference	Std. Error	Sig.
Black (B)	L	-15.45^{*}	4.53	.007
	M	-20.69^{*}	5.18	.001
	W	-23.91^{*}	3.45	.000
Latinx (L)	B	15.45^{*}	4.53	.007
	M	-5.24	5.11	.843
	W	-8.46	3.35	.088
Multi-Ethnic (M)	B	20.69^{*}	5.18	.001
	L	5.24	5.11	.843
	W	-3.22	4.18	.939
White (W)	B	23.91^{*}	3.45	.000
	L	8.46	3.35	.088
	M	3.22	4.18	.939

* significant at the alpha = .05 level

The first two hypothesis tests dealt solely with the treatment group. To gauge effectiveness within the district, the following hypothesis tests compared results on the ACT and pre-ACT for students in the control and treatment groups.

Hypothesis 3. There is no significant difference in ACT mathematics scores between 11th grade students who received regular instruction and students who received instruction using the SLP.

Of all the measures used in the study, the ACT is the only high-stakes test result that tied to each student's performance. For this reason, test scores on the NWEA and pre-ACT may not correlate perfectly to student knowledge, despite the school district utilizing the data for scheduling and placement in particular courses, like Advanced Placement (AP) or ACT preparatory classes. Analyzing the results from the ACT may prove more fruitful, as students are expected to create an account, pay a fee, and show up on a non-school day to receive their results. Because of these differences, the ACT mathematics sub score might be more indicative of students' true knowledge state for both the control and treatment groups.

There was a mean difference in mathematics ACT result when comparing students attending ACE Leadership Academy (treatment group) and those receiving a traditional instruction (control group). The treatment group ($n = 14$) had an average score of 21.36, while the control group ($n = 277$) slightly outperformed ACE with a mean score of 24.40. On the ACT, a college ready score is deemed to be a 22 on the mathematics subsection, and only the control group reached this benchmark (ACT, 2017). In order to proceed with a statistical test, Levene's Test for Equality of Variance was performed to ensure both the treatment group and control group were homogeneous. Since the p-value ($p = .116$) was greater than .05, the population variances are equal.

The control group outperformed the treatment group by a mathematics sub score of roughly 3 ($p < .05$; table 4.9). Thus, there is a statistically significant difference between students who had received traditional instruction and students who had received instruction using an Intelligent Tutoring System, as measured by the mathematics portion of the ACT, favoring traditional instruction. Further, Cohen's d indicates a medium effect size of the independent variable (school attended) on the dependent variable (mathematics sub score on the ACT).

Table 4.9

Statistical Comparison Between Control and Treatment Groups for ACT Results

Independent Samples *t*-test

		t	df	Sig.(2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
ACT	Equal Variances Assumed	-2.088	289	.038*	-3.040	1.456	-5.906	-.174
	Equal Variances Not Assumed	-1.710	13.858	.110	-3.040	1.778	-6.857	.777
Cohen's d:	.57197							

* significant at the alpha = .05 level

Hypothesis 4. There is no significant difference in pre-ACT mathematics score between 10th grade students who received a regular instruction and students who received instruction using the SLP.

There was a slight mean difference in mathematics pre-ACT result when comparing students attending ACE Leadership Academy (treatment group) and those receiving a traditional instruction (control group). The treatment group ($n = 168$) had an average score of

19.43, while the control group (n = 972) slightly outperformed ACE with a mean score of 20.22. On the pre-ACT, a college ready score is deemed to be a 22 on the mathematics subsection, and neither program reached this benchmark (ACT, 2018). The next procedure performed included a statistical test, Levene's Test for Equality of Variance was performed to ensure both the treatment group and control group were homogeneous. Since the p-value ($p = .282$) was greater than .05, the population variances are equal.

The control group outperformed the treatment group by a mathematics sub score of roughly 0.8 (table 4.10). As a result, the null hypothesis was not rejected, as there was not enough evidence to assume that there was a significant difference between students who had received traditional instruction and students who had received instruction using an Intelligent Tutoring System, as measured by the mathematics portion of the pre-ACT. Further, Cohen's d indicates that the effect size is rather small (table 4.10), which indicated that the difference between groups is negligible.

Table 4.10

Statistical Comparison Between Control and Treatment Groups for Pre-ACT Results

Independent Samples *t*-test

		t	df	Sig.(2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Pre-ACT	Equal Variances Assumed	1.79	1138	.073	.79	.442	-.07	1.66
	Equal Variances Not Assumed	1.87	236.54	.063	.79	.424	-.04	1.63

Cohen's d: .14989

Null hypotheses 1 through 4 reviewed a detailed comparison of student performance between ACE Leadership Academy and traditional instruction, and the results indicated that traditional instruction is more conducive to mathematics achievement. Next, in order to attempt to determine if minoritized students are benefiting from the alternative method of instruction, the following hypothesis was tested:

Hypothesis 5. There is no significant difference in pre-ACT mathematics scores among students by race/ethnicity and income status when using the SLP.

To have an idea about disaggregated student achievement, as measured on the mathematics subsection of the pre-ACT, data were reviewed and disaggregated by race and income status. After each level was accounted for, student performance was analyzed based on mean score and standard deviation for both the treatment group (traditional instruction) and control group (Summit Learning Platform at ACE).

Students who are not Free- and Reduced-Lunch Qualifying (FRLQ) generally score higher than FRLQ students, and the control group generally scores higher than the treatment group (see table 4.11). This was consistent with the research surrounding the achievement gap discussed within Chapter 2. There were a couple of exceptions, however. First, although Black students who are full-pay earned a higher average score in the treatment group, Black students who are FRLQ scored higher in the control group. Further, Latinx students who are FRLQ maintained a higher average on the mathematical portion of the pre-ACT when compared to their non-FRLQ counterparts. These data demonstrate a trend that may be concerning to school districts hoping to narrow the achievement gap through the utilization of educational technology. In order to analyze the trend for significance, the relationship among race, income status, and school attended was examined.

Table 4.11

Descriptive Statistics for pre-ACT Results Based on Race, FRLQ, and School Attended

Descriptive Statistics			
		Treatment	Control
Race	Income Status	Mean (SD)	Mean (SD)
Black	FRLQ (n = 40)	13.50 (1.73)	15.25 (3.28)
	Full-Pay (n = 52)	17.17 (4.12)	15.83 (3.66)
Latinx	FRLQ (n = 20)	20.00 (5.23)	17.25 (3.57)
	Full-Pay (n = 81)	18.33 (3.34)	19.33 (5.00)
Multi-Ethnic	FRLQ (n = 17)	13.00 (2.55)	17.17 (3.38)
	Full-Pay (n = 43)	18.60 (4.22)	20.55 (5.10)
White	FRLQ (n = 70)	19.45 (5.22)	18.54 (5.06)
	Full-Pay (n = 772)	20.14 (5.09)	21.02 (5.26)

The factorial ANOVA demonstrated significant results within the demographic groups based on race, but income status (FRLQ) and school attended (control vs. treatment) did not yield significant results (Table 4.12). Further, when analyzing the permutations of Race, FRLQ, and School, there were no combinations that yielded significant outcomes. Due to these results, the null hypothesis was not rejected. However, understanding which demographic categories of race yielded significant results may aid in future studies. Because there was at least one race in the demographic profile that was significant, a post hoc test was performed to determine which race yielded significant results. As future researchers may look to this study, it was helpful to clearly determine if a particular race demonstrated significant gains or losses after utilizing the Summit Learning Platform.

Table 4.12

Factorial Analysis of Variance for pre-ACT Results Based on Race, FRLQ, and School

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3534.25	22	160.65	6.36	.000
Intercept	22163.69	1	22163.69	872.69	.000
Race	768.76	6	128.13	5.05*	.000
FRLQ	84.44	1	84.44	3.33	.069
School	9.31	1	9.31	.37	.545
Race*FRLQ	107.96	5	21.59	.85	.514
Race*School	76.59	4	19.15	.75	.555
FRLQ*School	16.11	1	16.11	.63	.426
Race*FRLQ*School	120.78	4	30.19	1.19	.314
Error	28368.33	1117	25.40		
Total	492675.00	1140			
Corrected Total	31902.58	1139			

a. R Squared = .111 (Adjusted R Squared = .093)
b. * Result is significant at the alpha = .001 level

Conclusions and Summary

The results of the statistical analysis demonstrate that the SLP has a statistically significant positive effect on students' spring NWEA-MAP Mathematics score when compared with their fall score. With an average RIT score increase of nearly 4.4, students who utilize the SLP achieve at levels 60% higher than what would be expected of a typical high school student who takes the NWEA-MAP. An important aspect of the study involved the deeper analysis of which students benefit from this type of instruction. As demonstrated in Tables 4.7 and 4.8, FRLQ students achieved lower scores when compared to non-FRLQ students, and Black students earned lower scores when compared with any other demographic group. These were the only two differences that were significant when measured at the .05 alpha level.

In Chapter 5, the implications of these results for the field of education are discussed, weighing the potential benefits with the costs associated with implementing the facets of the SLP within a school building. Moreover, recommendations for future research are explored to address potential gaps in this study to make it more applicable to schools around the nation.

CHAPTER 5

DISCUSSION

The results of this study are interpreted in context of the research questions addressed and in conjunction with other relevant literature, as discussed in Chapter 2. Central to the analysis and discussion are the educational implications for both secondary schools and future research. To understand any potential ramifications this study can have on the field of education, it is crucial to have a grasp on policy reform that has shaped mathematics instruction over the past decades.

Overall, the physical structure of education has fundamentally remained the same over the course of a century. Students are often grouped in rows, placed in classrooms with other peers in the same age group, and proceed from room to room after a finite number of minutes. This structure affects learning outcomes for some students who benefit from more personalized learning. When compared to other countries, the United States consistently lags in standardized test scores and STEM skills (NCES, 2017). Policy changes in the 21st century have cut into this deficit, and the No Child Left Behind (NCLB) Act normalized the process of accumulating and tracking data (NCLB, 2002). By holding school districts accountable for their students' learning, the struggles of underserved populations became measurable. Moreover, government at the local, state, and federal levels could begin to quantify the effect on groups of students that received fewer resources, especially in high poverty urban districts (Linn et al., 2002). Later, the Obama Administration utilized Race to the Top (R2T) and Every Students Succeeds Act (ESSA) to address the deficiencies of the NCLB. Success was no longer measured only by a snapshot of school success. Instead, individual performances by underrepresented groups of students became a primary focus, as equity and social justice became driving forces within the method of curriculum delivery (ESSA, 2015). These policy reforms have resulted in positive movement for U.S. students when measured by the Programme of International Student Assessment (PISA) and on the Trends in International Mathematics and Science Study (TIMSS), but such movement has not occurred quickly enough or shown great enough improvement for politicians (Lowry, 2017). Moreover, mathematics has continually functioned as a gate-keeping course to college enrollment and retention of students. Thus, schools have attempted reforms aimed at improving pedagogy and addressing the achievement gap, which has routinely indicated that students of color and students coming from low income backgrounds perform worse than their more affluent peers (NAEP, 2017). Several scholars caution schools to look beyond numbers or “gap gazing” (Gutierrez, 2008), maintaining the causes of the achievement gap are more complex and multiple gaps exist in schools (Irvine, 2010; Ladson-Billings, 2006; Milner 2012, 2013). As technology has become more advanced, opportunities for blended learning have shown promise in supporting students who are performing behind their current grade levels.

One of the downsides of additional levels of accountability for school districts is the search for quick solutions and fast turnarounds. Entrepreneurial companies are stimulated by hopes of profiting from accountability; occasionally, districts purchase a product or system that does not effectively alter student learning. One common product involves an Intelligent Tutoring System (ITS), which attempts to simulate student learning, gauge a student’s knowledge level in a certain content area, and provide immediate feedback to the student and teacher in real-time. Clearly, there are several areas that can go wrong. If the ITS model does not accurately gauge student knowledge, then it is fundamentally useless. If the program is confusing for the student and they cannot navigate it properly, then the data gained cannot be used. Finally, if the feedback is inaccurate, presents challenges, or is not immediate, then instruction may not be appropriate. Even successful models are too often abandoned, as larger companies purchase them, they go bankrupt, or the technology becomes obsolete (Selwyn, 2015).

As the chapter progresses, a brief discussion of findings that addresses the research questions for this study sets the tone for discussion of implications of findings and recommendations for future research. This discussion will shed light on the original purpose of the study; to determine if there was a positive association between utilizing the SLP and achievement in mathematics. Highlighting the limitations of the study adds to the recommendations for future research. Final thoughts communicate the overall journey of this project and justification for educational technology to close the achievement gap.

Discussion of Findings

To determine if there was a positive association between the utilization of the SLP and student achievement, as measured by the NWEA-MAP, pre-ACT, and ACT, several questions were formulated.

Does the use of the SLP positively impact student achievement in mathematics?

When looking at pretest and posttest results among students in the treatment group, it was determined that their RIT scores grew by a statistically significant amount. With a computer-adaptive test like the NWEA, students tend to experience a median gain score of 2.7. In the treatment group, gains for all students averaged 4.36, an observed value 60% higher than would be expected.

Does the SLP support the needs of traditionally underserved populations, like Black, Latinx, Multi-Ethnic, and FRLQ students?

The answer to this question is complex. Yes, there is statistical difference when measuring the effects of race and FRLQ, but the benefits are still greater for certain demographic groups. For example, Black and Latinx students were the lowest performing groups on the pretest and experienced the smallest gains, as measured on the NWEA pretest. So, although the improvement was significant, as demonstrated in the previous question, White students benefited more from the utilization of the SLP.

Is the SLP more beneficial to student achievement than traditional methods of instruction?

Based on the statistical analysis conducted within the research, there was no difference between student achievement and method of instruction on the pre-ACT, as measured by the test scores of students who were taught via the SLP and traditional instruction. There was a difference favoring traditional instruction, however, when analyzing method of instruction and performance on the ACT test, with these students scoring 3.0 points higher in the control group. These results may be misleading, as the control group was much larger in size than the treatment group (n = 277 and n =14, respectively). In future studies, increasing the sample size to be more equivalent and maintaining current data could potentially impact these results. Additionally, these sample sizes were greatly impacted by the COVID-19 pandemic, which restricted student access to the ACT exam. In the study, only students from three grade levels were included, and more exposure to the SLP could potentially impact student achievement in a positive direction.

Can the SLP better meet the needs of underserved populations, like Black, Latinx, Multi-Ethnic and FRLQ students, than traditional models of instruction?

Based on the statistical analysis conducted within the research, there was no difference between student achievement and method of instruction. However, a post-hoc analysis within Hypothesis 5 demonstrated which of the categories of race were deemed statistically significant when compared to one another. Black students averaged a mathematics scaled sub score on the pre-ACT that was 3.3 points lower than Latinx students, 3.5 points lower than Multi-Ethnic students, and 5.1 points lower than White students. All of these were significant at the .01 alpha level. Latinx students averaged a mathematics scaled sub score on the pre-ACT that was 1.8 points lower than White students, which was significant at the .05 alpha level. It is crucial to note that these values shared in the post hoc analysis do not delineate students by school, but these results may provide better insight to provide an answer to the aforementioned question.

Implications of Findings

Before the novel Coronavirus (COVID-19) Pandemic, school districts were already seeking to support the varied needs of their students through the utilization of technological tools. Amid the reaction to the pandemic, schools have only increased their search as they seek to support students who are virtual learners (Adnan & Anwar, 2020). Further, the COVID-19 pandemic has ultimately forced the hands of many districts, opening the option of fully online education. For better or worse, school districts across the nation had to decide about their learning platform and its ability to meet the needs of students in an equitable manner. Implications of findings involve effective use of technology, personalizing classrooms, and culturally responsive leadership.

Making Decisions Regarding Effective Technology

Schools consistently on the cutting edge of effective pedagogical practices often look to technology to supplement instruction. However, when decisions about long-term solutions to a problem are made without adequate inquiry or research, a poor selection of technology may occur. Consumers often see that technology in their daily lives becomes obsolete nearly the moment it is taken home. Cell phones, cars, televisions, and even refrigerators utilize technology that has an end date. The same is true with ITS models, and the consistent changes lead to an unfortunate reality: There is simply not enough research in the field of educational technology to allow a school district to make a well-informed choice all the time (Bergman & Chan, 2019).

Despite the need for technological innovation within schools, many districts are choosing options that are untested (Barrett & Pas, 2020). Moreover, there is a lack of independent research to indicate the success or failure of a given program. The only research provided to schools is conducted by the organization destined to make money if their platform is chosen. Further, even when the research is performed, it is often conducted by the company itself, which leads to a conflict of interest. Such a reality creates a variety of problems, and the research conducted in this study was intended to fill a gap that currently exists in the larger body of educational research.

Understanding the effectiveness of ITS in schools and impact on student achievement is critical to make an informed choice on whether to commit thousands of dollars of resources. For this reason, the results from this study have a variety of ramifications for secondary schools and future research. As many schools are utilizing programs to support student learning at home, knowing if the Summit Learning Platform (SLP) is effective for students would be vital prior to switching from an alternate student learning platform.

Personalizing the Educational Process to Close Gaps

If an ITS can weave together understanding what a student knows and give them feedback in real time, it can truly personalize the educational process, and improve interest, motivation, and engagement in learning (Hwang & Chang, 2016). Moreover, the teacher can be freer in the classroom. Instead of teaching to the middle and spending time crafting a lesson that is only likely to meet most students' needs, the teacher becomes a facilitator who can support students at their current ability levels. As school districts have continued their search to find high quality educational programs that utilize technology to bridge achievement gaps, based on standardized tests, many have begun to turn to blended learning environments (Boelens et al., 2018; Smallhorn, 2017). Decision-makers at the building and district levels consistently seek to make the educational environment more personalized, and the most efficient way to do so is to utilize technology to track student progress, provide in-depth feedback, and allow for learning to be as fluid as the ability levels of the students. Commonly called authentic, rigorous, or real-world, these types of experiences allow students to take ownership over their learning by focusing on a student-centered, personalized approach. Unfortunately, such personalized instruction without the aid of useful technological research is nearly impossible to manage, as there is simply too much data for a teacher to sort through and assess in real-time (Taylor, 2017). Although not the original intent of this research, the study may have a wider impact, as more schools will be searching for ITS options that can be flexible no matter the modality of learning (online, hybrid, or face-to-face).

Culturally Responsive Leadership

Finally, this research has implications for the future of leadership roles within the field of education. When this study began, schools had the option to shift toward technology, but the pandemic and subsequent fallout removed the luxury of choice. Schools shifted toward a technological support structure that could assist students with their needs. As our nation has passed a year since the pandemic began, schools may begin to see a paradigm shift, as students may be inclined to remain in virtual learning settings. As such, schools must be able to incorporate technological tools into their instruction for years to come and choosing the right tool will be crucial for student and teacher success.

As highlighted in the literature review, personalized learning also requires a shift from looking solely at data-driven achievement to culturally responsive practices, and educational technology may be able to provide the personalization needed to bridge gaps that currently exist (Fraser & Lefty, 2018). Xie et al. (2019) suggest that personalized learning is a key paradigm to educational technologies with the categories of affective and cognitive learning as the primary measured learning outcomes.

This shift also requires culturally responsive leadership among administrators at all levels of the district including the central office, including conversations about race and inequities among students. Khalifa et al. (2016) communicates the importance of extending culturally responsive education beyond the walls of the classroom and to create a holistic environment that is responsive to all student needs. To successfully implement such practices, leaders must support teachers through professional development and mentoring.

Khalifa's (2018) outlines the following features of CRSL with attention to meeting the needs of teachers. Several of these include:

1. Promote a vision of a culturally responsive, equitable, and inclusive school. This strategy must start with a process for crafting a vision in partnership with "community-based voices, staff members, and students" (p. 156).
2. Foster high expectations to support academic identity. High expectations for students involve helping them attain school success through individual helping, tutoring, and academic support programs with support from the community. Every student should have plans for college.
3. Be a warm demander. Caring for students and their communities are strong messages of love and care. Warm demanders for minoritized students "[begin] with establishing a caring relationship that convinces students that you believe in them . . . principals must take the lead in developing teachers who are warm demanders.…" (p. 158)
4. Mentor teaching and support teacher modeling. Identify teachers who are culturally relevant and use community-based knowledge to mentor other teachers. Principals must take the lead in mentoring teachers who need help and emphasize the use of equity data regarding achievement and discipline issues.
5. Provide culturally responsive training and professional development. Schools often provide one-short professional development that centers on generalized content related to race, poverty, difference, or relationships. Limited attention is given to ways to shift conversations to institutionalized and sustainable practices and how to involve the community.

While supporting teachers for new growth and development to personalized learning in ways that value the needs of all students, leaders much also support mental needs and burnout among teachers.

As schools are facing the potential burnout of staff, which has been attributed to the stress and complexity of teaching in a pandemic, leaders need to cultivate new skillsets within their teachers (Marpa, 2020). To support teachers as they synthesize the immediate feedback that comes from technology, district leaders must be able to not only invest their time in the ITS models that can help staff, but also provide the in-house training so teachers can embrace their new roles of learning facilitators in an increasingly personalized educational setting. In their research regarding potential reasons for teacher burnout and high turnover within the field, Iancu et al. (2018) found meaningful training that utilized the feedback from staff members to guide future direction was important to sustaining initiatives long-term. Especially as districts reflect on the impacts of the COVID-19 pandemic, they must consider mental health, as recent studies have found increased levels of anxiety surrounding instruction, communication, and lack of administrative support as contributing factors to the struggles for students and staff members (Pressley, 2021; Sokal et al., 2020).

Recommendations for Future Research

First, it would be beneficial to have a more robust sampling across all secondary students in grades 6-12, as it would give a much better picture regarding the effectiveness of the SLP across grade level, gender, race/ethnicity, and income status. In the school district being studied, although some success was found within grades nine through eleven, there is no implementation of the SLP at the middle school level. Instead, there are a variety of platforms utilized across the district to supplement instruction. This is a common theme across districts and is a prime example of why research findings on the SLP are not necessarily relevant when analyzing additional software.

I had the opportunity to visit each of the schools within the study to observe instruction using the Summit Learning Platform (SLP). A major component of the SLP is the actual learning platform that gauges a student's knowledge state and provides immediate feedback. There are two other features of Summit Learning that are also folded into everyday instruction: Leadership and Mentoring. These features attempt to provide students with habits of success and a sense of purpose. While test scores can measure mathematics aptitude, they do not necessarily measure a student's resiliency or self-knowledge. Such characteristics are much better analyzed qualitatively, and future qualitative studies may show there is a difference in maturity and success at the post-secondary level.

Next, there is current inability to follow students to the post-secondary level. In all the schools within the study, there is a focus on post-secondary success. Due to the structure of the study and the infancy of the SLP within the district, there was not an option to perform any sort of longitudinal study. If some of the measures of success within a school include remedial courses being taken at the post-secondary level and college graduation, it would be helpful to understand how students utilizing each method of instruction fared during their transition. Along with other districts that have made changes to their curriculum delivery during the pandemic, I hope our district continues to follow students longitudinally in order to gauge the true effectiveness of the SLP. Such a process would bring more robust and impartial research to the field of personalized learning and adaptive learning technologies that are currently dominated by the entrepreneurial spirit of large companies, allowing school districts to make more informed, fiscally-sound decisions.

Finally, the results from the study indicated there may be a continuance of the achievement gap among students who utilized the SLP. Perhaps the most effective leadership framework to analyze and implement educational technology is neither transformational nor instructional leadership. Both theories of leadership lean more heavily toward the cognitive learning domain. Though transformational leadership does utilize the school community to develop and implement a common vision, it may not involve the stakeholders outside the institution as much as it should. To facilitate the development of students, leaders must create structures within schools where student identities are able to exist freely, without the impulse of exclusionary practice that many teachers possess subconsciously (Khalifa, 2013). As schools weave educational technology into the classroom to support the curriculum, leaders must ensure it does not continue the practices that marginalize underrepresented groups of students. Further, schools must invoke the support of the larger community to provide a connection for students. Khalifa et al. (2016) posit that culturally responsive education must expand beyond the walls of the classroom and create a holistic environment that is responsive to all student needs. This includes efforts to provide social justice education, self-awareness, and community advocacy. These beliefs are especially important within educational technology, which is why I would recommend that future researchers analyze student achievement using ITS models through a framework of culturally responsive leadership. Such an approach avoids the deficit depiction of students and families through the engagement of all stakeholders (staff, students, parents, and the community) in ways that positively impacts learning by remaining aware of cultural practices (Khalifa, 2020).

Conclusions

The original purpose of the study was to determine if there was an association between mathematics achievement and the SLP, an adaptive learning ITS model. Moreover, the research sought to find if there was an effect on underrepresented groups of students who were utilizing the SLP when compared to students who were participating in the traditional method of instruction. Statistical analysis determined that mathematics growth for students utilizing the SLP was statistically significant as measured by normative beginning and end-of-year assessments. Although this information is valuable, it does not address the question of "Is the SLP *better* than traditional instruction?" Regardless of the statistical tests, there is not a good way to answer the question with complete certainty, but hypothesis tests sought to provide a comparison between students in the control and treatment groups who took the ACT and pre-ACT. As a reminder, the control group consists of students who receive traditional instruction at two of the high schools and the treatment group includes students who learn the district-mandated curriculum utilizing the SLP. The conclusions gleaned from the research can best be summarized as follows:

- The SLP led to significant gains when students were compared using their pretest and post-test scores
    - Expected gain score, measured by Rasch Unit (RIT) was 2.7, as determined by NWEA
    - Observed gain score in the study was a RIT score of 4.4
- The SLP led to gains for the demographic groups in the study (Black, Latinx, Multi-Ethnic, White, and Free- and Reduced-Lunch Qualifying)
    - Black student had the smallest gains and the lowest pretest scores

    - FRLQ students had smaller gains than non-FRLQ students
- There was a statistical difference between the control and treatment groups on the ACT
    - The control group (traditional instruction) outscored the treatment group (SLP) by an average of 3.0
    - Number of students taking the ACT were lower than typical due to the inability and unwillingness of students to take a national test during the pandemic.
- There was no difference between the control and treatment groups on the pre-ACT
- There was no difference when comparing the performance of underrepresented groups on the pre-ACT across methods of instruction.
    - The treatment group did maintain higher average scores on the pre-ACT among Black students and Latinx students who are FRLQ
    - Black students scored significantly lower on the pre-ACT when compared with their peers in both the control and treatment groups

As the results within the conclusion imply, there is no way to state the SLP has a positive or negative impact on student achievement in mathematics when measured by multiple norm-referenced examinations. There are some benefits to using the SLP and some perceived issues, but the existence of several confounding variables could impact the study and its interpretation. Going forward, the cost-benefit must be weighed to fully discuss the implications the study has both on the local school district and others across the nation.

Limitations

There were several limitations to the study that occurred because of the design, availability, and circumstances around when the quasi-experiment was performed. First, there is only a single building within the district being studied that utilizes the SLP. Students have been added to the school in cohorts, with the first cohort starting in the 2017-2018 school year. Due to the closure of schools in the spring of 2020 and the lack of a senior class at the time of study, only 9th through 11th grade students were included as participants. Although the SLP is available to students in all grade levels, the research in this study can only be generalized to students in grades nine through eleven.

Secondly, the study can only be generalized to the learning software utilized. When the study began, there were many ITS models available to schools. One of the largest, called ALEKS, is widely utilized in both secondary and post-secondary institutions. All ITS models attempt to personalize the learning process for students and make data available for teachers to differentiate in real-time. The results from this study are limited to the SLP and no statistical analysis or subsequent conclusion can be applied to any other ITS model. Further, the study is not a comparison of ITS models, so there can be no conclusions made about the SLP being more effective or less effective than any other product.

The COVID-19 pandemic and reaction greatly impacted the ability to gather data. Due to the closure of schools, statewide testing was postponed. The school district within the study typically gives the pre-ACT and ACT to all students in the spring. Further, the treatment group takes the NWEA-MAP mathematics test three times throughout the year (fall, winter, and spring). Because the data from these canceled tests were not available, I had to utilize data from the previous school year. As a result, the sample sizes were smaller than initially anticipated, especially for Black, Latinx, and FRLQ students who took the ACT. Moreover, any training for teachers during the 19-20 school year, especially in the treatment group that utilized the SLP, would not be reflected in the conclusions being made.

Another limitation to the study was the ability of students to choose their school of attendance. Because students effectively have the choice to attend a traditional school (one without the SLP) and one that employs the SLP, there is concern about self-selection bias. Additionally, students can elect to move from one school to another at the end of each school year, which convolutes the data results. To mitigate these concerns, these data points were removed via listwise deletion.

Finally, the results gleaned from this study do not necessarily speak to the overall effectiveness of the blended learning model. Instead, the results may be derived from teachers' relationships with students, their understanding of culturally relevant pedagogical practices, and their willingness to consider their own conscious and unconscious biases. There are various implementation strategies and styles within many school districts across the nation. Any statistical significance or positive results from this study can only be attributed to the blended learning model utilized within the research design.

Final Thoughts

Since the inception of public education and compulsory attendance, the routines and physical look of school has changed very little. While the factory model of education was necessary to support the workers required to fuel the Industrial Revolution, its utility has in many ways run its course. Although it may be the most efficient way to educate a mass number of students, it is not necessarily the most effective. In order to usher in change, reforms began to support innovation within the field of public education. Such innovation, however, needed to be tracked and measured, and schools were held accountable for their students' performance. To support a newly created need for norm-referenced assessments, mathematics was chosen as the primary subject area to consistently assess achievement and growth levels. Because mathematics education has been the primary gatekeeper for many students at both the secondary and post-secondary levels, districts began to employ strategies to support learning objectives that were tested. Further, as data began to show that minoritized students and those from lower socioeconomic backgrounds performed at a lower level on standardized assessments, states began to focus on narrowing the newly defined, though always present, achievement gap. Though pedagogical best practices have improved results for all students, ultimately White, middle- to high-income students are still benefiting the most. As schools utilize financial and human resources to tackle the issue, it seems more necessary than ever to change the fabric of the educational institution.

It may be entirely fitting that as our nation begins another Industrial Revolution, we seek to automate aspects of education using technology. Within most classrooms, the goal is to consistently differentiate instruction in order to meet students' needs, but all too often, this proves impossible due to the varied needs of students within the class. Technology can personalize the learning process and present more viable solutions to teachers as they look to address individual deficiencies in the knowledge level of students. Further, by automating aspects of the classroom, it no longer is confined to its four physical walls of a classroom. Learning and feedback can be provided anywhere. This has the potential to allow students to catch up on skills they were lacking or were not developmentally able to learn. After all, it seems that to narrow the achievement gap, perhaps schools need to remove the barriers that contributed to the gap in the first place. This idea, like most reform efforts, is sound in theory, but putting it to practice becomes more convoluted as schools and communities need to determine their priorities while measuring student needs.

Schools have continued to push initiatives that provide one-to-one access to technological devices to promote equitable opportunities for students. Such an approach, however, creates two problems. First, it is an expensive undertaking for the school district, as staffing needs change and devices must be replaced. Second, it can create financial strain on families who do not have access to internet options that support digitizing classroom instruction. In this way, it can widen opportunity gaps for students. For this reason, many districts delayed or abstained from making a full implementation of one-to-one device rollout. The trend appeared to be toward increasing technology in classrooms, but the fallout from the COVID-19 pandemic forced the hands of many districts. Overnight, they needed to create policies and procedures to support their student information system (SIS) and ITS model, if one existed. As schools seek to return to normal, they seem to be finding that there is a "new" normal.

Across all business models, technology has increased efficiency levels and lifted productivity. Education will have to adapt if it seeks to optimize education for all students and begin to provide equitable opportunities. ITS models like Summit Learning Platform can ease this transition, as face-to-face traditional instruction remains a piece of the overall delivery model, but teachers shift into the role of facilitator. Due to the potential and current demand by districts at the national and global levels, education-based technology is flooding the market and school districts must navigate a moving target to find what may work best for students and staff. Because many of the software options are newly developed, there is not a plethora of independent research that districts can fall back on in order to make informed choices as they begin the transition into a blended learning or fully virtual model.

Although there are challenges to reviewing and incorporating ITS models into a school's blended learning environment, there are steps it can take to ease the transition. For example, surveying all educational stakeholders, piloting various ITS models, analyzing the most recent literature and studies, and visiting school districts already utilizing the technology are all ways to optimize the decision-making process. The SLP is one such adaptive learning ITS model that has a research-based, demonstrated theoretical framework based on Knowledge Space Theory (KST) and Adaptive Control of Thought-Rational (ACT-R). These two theories intertwine within the SLP to determine exactly where a student's knowledge level lies and interact with the student to provide effective feedback. Although more research needs to be performed, the SLP has yielded promising results for mathematics achievement within this study. Finally, I hope this study can fulfill a need for independent research on the SLP while also inspiring others to continue to make contributions to the literature in this growing field, thus allowing educational leaders to make decisions to better meet the needs of all students.

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VITA

Andrew Haws was born on July 28, 1987 in Rochelle, Illinois. After graduating Rochelle Township High School, he attended Truman State University in Kirksville Missouri. After completing his undergraduate degree in mathematics, Andrew also earned a master's degree in education. Education was chosen as a career field because Andrew was passionate about social justice and believed that public education was the best way to combat systemic and institutional racism. He started teaching high school in Smithville, Missouri, and earned his master's degree in educational administration in order to pursue a position in leadership.

After working in Smithville for five years, Andrew moved to Kansas City, Missouri to teach at a Park Hill High School. After three years, he was promoted to the position of administrative intern, where he has tackled the district-wide move to a Multi-Tiered System of Supports (MTSS). Under this new model, restorative justice practices have been implemented to support the varied needs of students. Further, as the district has sought to incorporate various technological products to support the shift to online learning, Andrew has seen firsthand how Intelligent Tutoring Systems (ITS) have both benefited and failed students within his district. As the district seeks to move forward with online learning even after the pandemic, Andrew hopes to support the district with relevant research relating to student learning using ITS models.