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Brian R. Rathmell

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Approved:

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Chairperson	Date
Redacted	4/4/2018
Committee Member	Date
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If applicable:

Additional Committee Member	Date
Additional Committee Member	Date

Approved:

Redacted	4.17.18
Graduate Program Director	Date
Redacted	4/18/18
Dean of the Unit	Date
Redacted	4-4-18
Graduate School Representative	Date

Abstract

Classroom computer integration and the proliferation of computer-adaptive learning programs in K -12 schools continue to advance. Academic success, as well as the social and emotional well-being of students, is critical in American schools and the role of the teacher and student-teacher relationships impact these academic, social, and emotional factors. The integration of computer-adaptive learning programs into America's elementary classrooms impacts the role of the teacher and relationships between teachers and students, placing a priority on the study of these programs and their effects. The purpose of this research was to examine how teachers perceive their role and relationships with students in classrooms where computer-adaptive programs have been introduced. This study fills an existing gap in the literature by exploring the changes taking place within classrooms that have implemented modern computer-adaptive programs and identifying how teacher role and student-teacher relationships are affected. The following two research questions helped guide this study (a) *How is teacher role impacted through the implementation of computer-adaptive instruction programs?* (b) *How do teachers perceive their student-teacher relationships through the implementation of computer-adaptive instruction programs?* This inductive qualitative study used participant interviews and classroom observations to examine seven teachers' perceptions and experiences of computer-adaptive program use. Eight main themes emerged that provide insight to help understand the dynamics occurring in today's elementary computer-adaptive-classrooms. Five themes emerged to describe teacher role: Teachers as personal instructors, individualized instruction, teacher trust in and deference to programs, role shift from learning facilitator to program assigner, and teacher as classroom and instructional leader. Three central themes emerged to describe student-teacher relationships while using commuter-adaptive programs: Teacher proximity, communication, and support. Elementary teacher perceptions of their role and relationships with students through the implementation of computer-adaptive math programs were framed using the Actor-Network Theory to model the connections between teachers, students, and programs within computer-adaptive classroom networks. Upon considering these connections, educators and education leaders will be better informed when implementing or choosing not to implement computer-adaptive instruction. Education leaders should be mindful, throughout the implementation of any education technology program, that the programs in use can have both positive and negative effects on the role of the teacher in the classroom. Without an understanding of the role shift of teachers who integrate computer-adaptive programs, school leaders risk disenfranchising the very people who are needed to maintain positive and healthy interpersonal relationships within school walls.

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Dedication

This study is dedicated to students and teachers of tomorrow and today. Students who will inevitably be exposed to computer-adaptive instruction and teachers who will continue to find ways to keep meaningful connections with students in the presence of artificial intelligence.

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Chapter One: Introduction

Significant changes have impacted teaching and learning over the past several decades, many of which have been spurred by the readily available masses of classroom computing devices. The use of computer technology as an educational tool is steadily advancing in U.S. schools, especially for math instruction, and much of this change is in the form of blended learning (Horn & Staker, 2011). A blended-learning model is defined as the integration of computer-mediated instruction with face-to-face instruction and has been used since the 1960s beginning with programs like the Programmed Logic for Automatic Teaching Operations (PLATO) (Bersin, 2004) but continues to gain traction in more schools. Schools and districts continue to build more capacity to offer online and computer-based instruction and resources for students. From 2013 to 2014, over 23 million personal computers and tablets were purchased by schools for classroom use (Harrold, 2016). Cheung (2013) declared that education technology is so ubiquitous, the question is not whether teachers should use it, but how to best integrate it into the curriculum.

Despite this increase in growth of education technology, Drysdale, Graham, Halverson, and Spring (2013) showed that only eight percent of research on blended learning has been in the context of K-12 instruction and most research on the topic is related to corporate or higher education. These studies have shown positive outcomes in support of blended learning practices, yet the specific reasons for why blended learning is more effective remain inconclusive (Means, Toyama, Murphy, & Baki, 2013). Drysdale et al. (2013) note a clear need for research on implementation of education technology programs.

The National Education Technology Plan put out by the United States Department of Education (USDOE) in 2010 places technology as a key component of effective teaching methods. Within some blended-learning environments, there is a current push to create personalized learning pathways for every student. This initiative has encouraged placing more advanced technology into classrooms (Bellanca & Brandt, 2010; Silva, 2009). This advanced technology includes computer-adaptive and analytic tools that develop and affect student learning by tracking student response data and adjusting the content, pace, and trajectory of lesson sequences. With the increase of the availability of classroom computers and a growing trend of computer-assisted instruction, computer-adaptive instruction (CAI) programs are being implemented in K-12 settings across the nation and are providing relief for schools trying to personalize instruction for their students. Computer-adaptive instruction provider revenues totaled approximately $200 million in 2012. Five major providers of CAI, including industry strongholds like Pearson and McGraw Hill, have enrolled over 11.5 million student users to date (Herold, 2017).

Computer-adaptive instruction programs collect, track, and utilize student data to guide and deliver lessons. They are intelligent tutoring systems that rely upon code driven learning analytics to determine the optimal learning path and pace for individual students based on student response data. If CAI becomes the predominant form of instruction for students, it has the potential to isolate students from peer and teacher interactions that can deepen learning and provide formative socio-emotional experiences (Steele, Johnson Palensky, Lynch, Lacy, & Duffy, 2002). Social learning interactions and communications that normally took place within the classroom could be circumvented by students interfacing with adaptive-programs through computer screens on a personal level and autonomously. The social component to learning and the student-teacher relationship are fundamental to the classroom environment and more importantly, fundamental to the academic success and well-being of each student within the class (Finn, 1993; Hamre & Pianta, 2006; Marks, 2000). It is important to know how the introduction of this new take on adaptive learning, with abilities to monitor, predict, communicate, and adjust content delivery, will interact with the social aspects of the learning environment, particularly the relationships between teachers and students.

Hattie's (2009) compilation of meta-analyses of research relating to student achievement helps to comprehend the effects of computer integration in education. Hattie (2009) compiled 76 meta-analyses (N = 3,990,028) on *computer-assisted instruction* and effects on student achievement and determined a relatively low effect size (d = 0.37) across the studies. A lower effect on achievement (d = 0.18) was seen from *web-based learning* across 45 studies (N = 22,554). *Programmed instruction*, defined as the presentation of subject matter to students in a sequence of controlled steps, showed a similarly low effect on student achievement (d = 0.24) across 464 studies. *Instructional video methods* showed a higher effect on student achievement (d = 0.52) across 441 studies (N = 4,800). These effects can be compared to the typical effect (d = 0.40) related to natural development and teacher effects.

In contrast to the relatively low effects of attributes related to computer-adaptive programs, Hattie's (2009) research determined higher effects on achievement from *student-teacher relationships*. Student-teacher relationships were analyzed through 229 studies (*N* = 355,325) resulting in a high effect (*d* = 0.72) on student achievement. With a greater impact on learning from student-teacher relationships than modern technological advances, one must consider the impact on student-teacher relationships from computer-related initiatives including computer-adaptive programs.

Effects of teacher role were also noted by Hattie (2003), as expert teachers are shown to combine new subject matter with prior knowledge and relate current lesson content to other parts of the curriculum. In doing so, teachers make lessons uniquely their own by modifying them to meet the needs of their students. In a synthesis of over 500,000 studies, Hattie identified instructional quality (*d* = 1.00), direct instruction (*d* = 0.82), and remediation/feedback (*d* = 0.65) to be of the top teacher-based influences on student achievement. All three of these teacher influences are potentially altered by the implementation of computer-adaptive programs as the instructional content, method of delivery, and remediation/feedback are all provided by programs.

Anrig (2103) noted the scarcity of research on the impact of increased technology on student-teacher relationships, yet he asserted that effective technology use hinges upon these relationships because technology should be used for greater collaboration, communication, and problem-solving. According to Linke (2013), the borders and connections between humans and technology continue to blend and point to a relevant starting point of further investigation. Student-teacher relationships, viewed as a product of teacher characteristics and instructional style, have an impact on student outcomes (Finn, 1993; Hamre & Pianta, 2006; Marks, 2000); exploration of this relationship as it relates to educational technology needs further research (Evans, Harkins, & Young, 2008). Since much of the mounting education technology research is on the effectiveness of blended learning and how, in some cases, the results point toward student gains, it is important to consider how educational technology use is affecting relationships within the classroom.

Purpose Statement

It is assumed that positive and effective student-teacher relationships are best for students. As such, it is important to understand distinct characteristics that strengthen student-teacher relationships through interpersonal interactions and teacher role. Conditions in classrooms continue to change as human-computer interaction increases. With widespread growth of 1-to-1 classroom computer initiatives, the circumstances under which students learn are shifting (Bebell & O'Dwyer, 2010). As instruction moves from teacher delivered to computer-driven lessons, attention should be paid to how these computer-mediated environments are affecting the relationships within the classroom. If some of students' interactions with teachers are replaced with personalized programs using interactive screens, and students communicate and build relationships with virtual tutors, it is important to know if the classroom teacher's ability to connect with students is altered and how this change affects the classroom environment and accompanying social interactions. The purpose of this research was to examine how teachers perceive their role and relationships with students in classrooms where CAI programs have been introduced. The following two research questions helped guide this study:

1. How is teacher role impacted through the implementation of computer-adaptive instruction programs?
2. How do teachers perceive their student-teacher relationships through the implementation of computer-adaptive instruction programs?

Significance

This qualitative study explored teacher role and student-teacher relationships within classrooms that implemented CAI programs, to better inform the teachers and districts attempting or considering CAI implementation. In doing so, this study addressed a current research gap around the implementation of CAI and the nature of student-teacher relationships in the presence of these programs. Insights gained from this study can assist teachers and education leaders deciding if CAI is the best choice for their students, or how best to implement a program. For districts already using CAI, this study can inform improved educator development and collaboration around CAI use with a focus on the effects of interpersonal relationships, communication, feedback, and support. Additionally, results provide valuable information to teachers and leaders on how to adjust and support practices that empower meaningful social interaction while being cognizant of potential student isolation via personalized learning.

A deeper understanding of the factors that contribute to positive student-teacher relationships and the state of those relationships in the presence of CAI will inform decisions on how to integrate technology into the classroom best while strengthening the necessary connections between students and teachers. Teachers, by the nature of their jobs, are leaders of their classrooms; as they are in charge of establishing learning objectives, creating lesson plans, and managing the classroom environment to optimize student learning. It is important to understand student-teacher relationships in situations where the teachers' roles as leaders of their classrooms have been impacted by the introduction of CAI and its ability to influence the educational and social environment.

Schools still struggle with effective implementation of online and computer-based learning programs. Jude, Kajura, and Birevu (2014) note the primary reason for non-use of education technology is teachers' lack of know-how on using particular hardware or applications. From a teacher's perspective, it may be easier to administer CAI programs to students than create lessons and differentiate instruction with online delivery. To increase participation in educational technology programs, non-monetary incentives such as certificates of recognition, new devices, and attending conferences are sometimes provided to staff who decide to employ new technology. These incentives, along with the notion of meeting the personalized needs of each student, can be attractive reasons to incorporate CAI programs (Jude, Kajura, & Birevu, 2014). Yet, lackluster implementation of educational technology policies and the absence of a strong team to drive the implementation process can lead to less effective implementation, which can include inattention to teacher communication, support, and relationships with students.

With an awareness of the relationships in the classroom, teachers need specific training in working with online tools and digital learning resources to maximize the use of learning technologies (Handal, Campbell, Cavanaugh, Petocz, & Kelley, 2013).

Despite this need for technology training, ongoing teacher learning experiences rather than specific training sessions have shown to affect the quality of the development of teaching practices positively. Effective programs have allowed teachers to gradually gain ideas for integrating technology which then provided opportunities for teachers to share their experiences with colleagues (Tondeur, Kershaw, Vanderlinee, & Van Braak, 2013). According to Drent and Meelissen (2008), as teachers learn in this way, they are willing to keep contacts with colleagues who can assist them with technology integration and professional development.

The results of this study could aid the design of 21st-century learning environments that develop increased student social, emotional, and academic success. Whole-child education can benefit from a study that identifies and explains critical factors of student-teacher relationships in classrooms implementing computer-adaptive programs.

Rationale

An inductive qualitative research design was chosen because this study sought to obtain teachers' perspectives on experiences within their classrooms and relationships with their students. Inductive analysis was employed because teachers' perceptions of these newly implemented technology programs were unknown, and this research sought to describe and understand the experiences currently taking place in classrooms.

As this work sought to understand the elementary teachers' world and their work within that world, including teacher-student interactions as described by the teacher, in-depth interviews were chosen as the primary mode of data collection. Observations were selected to provide data that may confirm or expand upon data collected through participant interviews.

Because constructed meanings are expressed through language, both implicitly and explicitly (Spradley, 1980), interpretivism can be used to bring understanding the complexities of those expressions. Interpretivism was used to examine the socially constructed and changing reality of the participating teachers. Glense (1999) posits that social realities are a construct of the participants in social settings. To better understand the nature of these constructed realities, “qualitative researchers interact and talk with participants about their perceptions…to seek out the variety of perspectives; they do not try to reduce the multiple interpretations to a norm” (p. 5). For these reasons, participant interviews and classroom observations were chosen to be analyzed in hopes of gaining new perspectives on the implementation of CAI programs and how they can best be used or not used while supporting positive student-teacher relationships.

Theoretical Framework

Communication has underpinned the foundation of educational inquiry since antiquity. Within a learning environment, every chosen action is a form of communication, just as every chosen inaction is also a form of communication. Communication affects the social space within the learning environment, a social space that students use to form their ideas and mold their behaviors. Student-teacher relationships rely upon and are affected by communication within the learning environment. The resultant perspective from actor-network modeling with aspects of social learning theories creates a framework to illuminate factors of teacher role and student-teacher relationships through the implementation of computer-adaptive programs.

A program working with a student, and customizing to their ability level, can provide more frequent feedback than a teacher rotating through the students in a classroom. Student-teacher and student-program connections necessitate communication, and this study is concerned with how the connections between students, teachers, and programs impact teacher role and student-teacher relationships. Teachers highlight the need for students to interact with one another and the teacher in order to learn. As such, teachers believe in the social sphere as a critical space for knowledge acquisition. Actor-Network Theory (ANT) (Law & Bijker, 1992) allows computer-adaptive programs to be seen as part of the classroom social sphere in a three-actor learning network; a network of students, teachers, and computer-adaptive programs.

Teachers in this study expressed belief in social interaction and communication around mathematical topics to be instrumental for student learning, and these views of social learning are best represented through Social Development Theory (Vygotsky, 1978) and Social Cognitive Theory (Bandura, 1986). This social interaction in the classroom includes interaction with a non-human actor, a computer-adaptive program. A unique perspective of teacher role and student-teacher relationships in the presence of computer-adaptive programs is available when modeled with ANT (Law & Bijker, 1992).

Actor-Network Theory. The purpose of ANT is to show how actors and networks are constructed and to give tools to analyze them. Actor-Network Theory views society as an ongoing process of development and attempts to explain society as it evolves (Callon, 2001). The attempt to explain the changing nature of a technology-infused society distinguishes ANT from other constructivist approaches. As such, ANT does not recognize purely social or purely technical relationships; rather it sees the two as inextricably connected and attempts to describe their interconnectedness (Law & Bijker, 1992). With this view, experiences of tension and connection among actors help bring meaning to relational factors and effects of and to actors in the network. Actor-Network Theory allows interpretation of data to accept and take into account the ever-changing nature of relationships and dynamics among actors in a classroom environment.

Actor-Network Theory sees human and non-human actors as equivalent elements within a network, each with their own agency. The sometimes-difficult proposition of assigning agency to a non-human is a key tenet of ANT and is important for educators trying to understand computer use in schools and its effects on the roles of actors (Callon, 2001). In the current study, teachers, students, and computer-adaptive programs are positioned as actors within the computer-adaptive-classroom network. Depicted in Figure 1, ANT is used as a framework to examine the roles of teachers within computer-adaptive classrooms and the teachers' experiences of the interrelationships between themselves, students, and computer-adaptive programs.

Figure 1. Computer-Adaptive Classroom Network

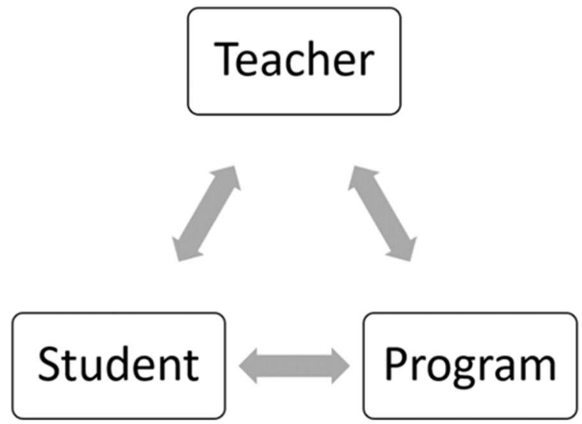

Figure 1. Actor-Network Theory situates teachers, students, and programs as autonomous actors with the capacity to interact and impact one another, comprising a network.

According to Callon (2001), ANT can assist educators as they attempt to understand their relationships with new technologies and with their students. It takes into account the unclear nature and non-uniform actions of each actor in the network and recognizes the work necessary to keep each piece of the network bound together. This understanding is critical to educators as they decide what work to delegate to programs and what work programs to delegate to educators.

Social Development Theory. According to Britt (2013), education is not just mediated by student-teacher interaction, rather the interaction itself is education. Teaching and learning require interpersonal relationships including the relationship between students and teachers. In his theory of social development, Vygotsky (1978) theorized that humans are inherently social; therefore, learning and development originate from experiences relating with others. Adults are an important source of children's cognitive development by demonstrating and transferring methods of intellectual processing that children internalize. This study views student learning through Vygotsky's Social Development Theory (SDT) (1978) in which social interaction is fundamental for cognitive development and learning is a product of society and socialization. Vygotsky identified three main tenets of SDT: social interaction, more knowledgeable other, and zone of proximal development. The connections between people and their sociocultural environment are foundational to SDT. A more knowledgeable other is a person or program that contains greater ability than the student around a concept or skill. The zone of proximal development exists in the space between what a student can do on their own and what they can do with assistance.

This aligns with Bandura's Social Cognitive Theory (1986) in that learning is socially manifested, and students gain and process information from social interaction. Through this lens, we see student-teacher relationships are necessary for learning. As such, students learn with the teacher as the primary facilitator within the social classroom environment (Arievitch & Haenen, 2005). With the introduction of CAI, the learning environment is positioned to shift, leading to changes in student-teacher and student-student interactions that affect learning.

Summary

Student-teacher relationships vary for many reasons; teacher expectations, personality differences, communication styles, classroom management strategies, level of teacher support, individual student needs, and available resources are just a few examples of the variables that contribute to the relationships between students and teachers. These variables will differ from classroom to classroom and from student to student, but research is clear that when any of these variables contribute to positive student-teacher relationships, student academic and social outcomes improve (Carlisle, 2011; Elder, Johnson, & Crosnoe, 2004; Hamre & Pianta, 2001).

Modern education technology such as personal computers, tablets, and the array of accompanying applications and programs has become widespread; the emphasis is now on how to use it, not whether to use it (Cheung, 2013). The use of computers is increasing, especially in math classes; and blended learning continues to impact and transform modern education (Horn & Staker, 2011). Integration of educational technology such as digital media and instruction via adaptive programs has been around for years, but new programs have been developed with analytics to predict student performance and adjust content delivery to personalize instruction beyond what was previously possible. With the growth of 1-to-1 computing environments, the dynamics within classrooms are shifting (Bebell & O'Dwyer, 2010). As instruction moves from teacher-created-and-delivered to computer-driven lessons and feedback, attention should be paid to how these CAI programs impact relationships between students and teachers. This study fills an existing gap in the literature by exploring the changes taking place within classrooms that have implemented modern CAI and identifying how student-teacher relationships are affected or modified. With this knowledge, educators and education leaders will be better informed when choosing to enter or not to enter the world of CAI.

The following chapters examine these new programs from teachers' perspectives and seek to understand the dynamics that do or do not occur following program implementation. Chapter Two provides the background information and supporting literature to understand factors attributed to effective student-teacher relationships, technology-enhanced learning that includes CAI, and the intersection of those person-person and person-adaptive program relationships. Chapter Three lays out the qualitative methodology, sample population, and study design. Chapter Four reports the coded and analyzed interview data of teachers' perceptions of student-teacher relationships through the implementation of CAI. In Chapter Five, a discussion of the results points toward conclusions and potential next steps for research and implementation of CAI programs.

Chapter Two: Review of the Literature

The following chapter outlines the increased use of technology in education, including the design and use of modern CAI programs that are built to meet the individual needs of each student. The role of the classroom teacher and the factors that comprise relationships between teachers and students are also detailed in an effort to form a baseline from which to study the effects of computer-adaptive programs on the interactions between teachers and students. The chapter concludes with a look into the interactions that take place between humans and intelligent non-human programs that have the potential to disrupt traditional student-teacher relationships and the shifting roles of teachers that integrate such programs.

A broad view of the current education technology research provides a sense of what many researchers are seeking to discover and which areas are lacking study. Drysdale, Graham, Halverson, and Spring (2013) showed that only eight percent of research on blended learning has been in the context of K-12 instruction. The majority of research on the topic is related to corporate or higher education. Thirty-three percent of studies that have been conducted are related to instructional design and best practices. Twenty percent of studies are comparisons between blended learning and face-to-face instruction. These studies have shown positive outcomes in support of blended learning practices, yet the specific reasons for why blended learning is more effective remain inconclusive (Drysdale et al., 2013).

According to Linke (2013), the borders and connections between humans and technology continue to blend and point to a relevant starting point of further investigation. Student-teacher relationships, viewed as a product of teacher characteristics and instructional style, have an impact on student outcomes and exploration of this relationship as it relates to educational technology needs further research (Evans, Harkins, & Young, 2008). Since much of the mounting education technology research is on the effectiveness of blended learning and how, in some cases, the results point toward student gains, it is important first to understand how educational technology use has led to improved outcomes.

Effects of Education Technology on Student Achievement

For the purpose of this research, the term *education technology* refers to technology-based programs and hardware that assist in the delivery of learning materials and otherwise support the learning of academic content. Examples of education technology programs include learning management systems (LMS), computer-assisted instruction, and CAI programs. Hardware that meets the criteria for this definition of education technology include personal computers, tablets, and mobile devices. According to Cheung and Slavin (2013), over 20 major reviews of education technology have been conducted over the past 30 years and the majority of these studies have concluded that technology applications show positive effects on student achievement with low to moderate effect sizes ranging from 0.10 to 0.50.

Smaller case studies and mathematics-specific studies show similar results. For example, research conducted by Eyyam and Yaratan (2014) compared seventh-grade math students (n = 82) using technological tools with students receiving traditional non-technological instruction. Academic posttest results indicated a significant difference between the experimental and control groups, (F (1,73) = 7.12, p = .024), showing that students who were instructed using technology scored statistically significantly higher than those in a traditional setting. Results like these continue to lend support for increased technology applications in math classes.

Cavanagh and Mitchelmore (2011) explained that educational technology used for low-level tasks such as drill and practice have shown no significant effect on student learning outcomes. This is attributed to the formats closely resembling printed versions of similar rote learning exercises. The findings of Cavanagh and Mitchelmore contrast a meta-analysis of 254 controlled evaluation studies by Kulik and Kulik (1991) which cover students ranging from kindergarteners to adults and show computer-based instruction usually produces positive effects for students. Lei and Zhao (2007) have shown that both the quantity and quality of technology usage impact student achievement. In a study of 130 middle school students in Ohio, Lei and Zhao found that students who used technology at school for more than three hours per day experienced a decrease in achievement. Conversely, students who utilized technology for one to three hours per day demonstrated an increase in academic achievement. Lei and Zhao suggested that the quality of the technology needed to be ensured before the quantity of time on computers increased, otherwise the increased computer time could cause more harm than benefit. The difference in GPA change between the two groups is statistically significant (t (128) = 4.122, $p < .001$). In regards to quality of technology use, students who were involved in higher level tasks such as webpage development and programming had increased achievement compared to students using technology for basic tasks such as taking notes with a word processing program. However, the researchers did not report any interaction effects of quantity and quality on student achievement.

A recent meta-analysis (Cheung, 2013) of 154 studies involving approximately 120,000 K-12 students revealed several important classroom technology usage factors. Programs that required students to use computers 30 minutes or more per week had a larger effect on student achievement than ones that required less. The level of implementation was also a contributing factor to student achievement. The average effect size of programs with higher levels of implementation (ES = .02) was significant yet very small when compared to programs with lower levels of implementation (ES = 0.05). While Cheung reported these findings as significant, the effect sizes are so small that little effect can be attributed to the level of implementation. Cheung's analysis also suggests that education technology has a more positive effect on secondary students (ES = 0.22) than on elementary students (ES = 0.14).

The use of Khan Academy in elementary and middle schools in Los Altos, California exemplifies successful implementation of educational technology at the end-user level. Khan Academy is a free service that provides over 2,500 short videos, each describing a discrete concept. Students can access lessons at any time with or without proceeding through a sequence of prerequisites. Per Pugliese (2016), if teachers direct students to proceed through the recommended sequence, Khan Academy can be considered a rules-based adaptive system based on its linear sequencing and assessment feedback which provides little adaption other than individualized pacing. Teachers using Khan Academy for their digital content have witnessed the motivational effects of immediate feedback and recognition (Kronholz, 2012). Khan Academy utilizes gaming features that can act as motivators for students. Students are challenged to complete a series of 10 computer-generated math problems. If a student answers a problem incorrectly, they need to restart the set of problems. After a set of 10 questions has been answered correctly, students earn energy points. Badges are awarded for demonstrating behaviors like working quickly or gaining proficiency with certain concepts such as the Pythagorean Theorem. The instruction was differentiated as students worked on computers independently moving through lessons at their own pace. Of the seventh-graders who used the program including all remedial students, scores of proficient or advanced on the California Standards Test (CAT) rose from 23% to 41%. Ninety-six percent of the fifth-graders achieved a proficiency or mastery rating, compared to a 91% proficiency or mastery rating district-wide (Kronholz, 2012). While the advanced analytics in other CAI programs can provide a far more personalized instructional sequence than what Khan has provided, Khan Academy showcases a starting point for the potential of CAI programs to impact today's classrooms.

The research on technology integration and student achievement can be convincing for education leaders looking to improve student learning outcomes. Within just the few aforementioned studies, one can see a variety of ways the research points to effective technology use. It should be recognized that most studies focus on student academic outcomes, regardless of the level of student social or emotional development. The backbone of selective positive research findings of general education technology integration provides a baseline of support for proponents of personalized and 21st-century learning. Teachers, administrators, and policymakers looking for ways to utilize technology to improve student outcomes can also turn to CAI programs to personalize instruction for their students.

Students as Technology Users

As educators integrate technology into curricula, it is important to specify the goals for the technology use. Not all students will use technology in the same way. Gasson and Haden (2014) identify four types of technology users. A *theoretician* is at the upper end of the computer science field, researching and developing new computer science theories. *Practitioners* are hardware or software developers or individuals who maintain computer systems. A *power user* is an expert in another field who understands and uses complex computing tools for their needs. To become power users, students must develop the ability to think computationally and utilize these advanced computing tools to solve complex problems. An *end user*, on the other hand, simply applies commercial software and hardware for non-specialist use. Examples of end use would include video tutorials, instructional games, word processing, and apps. Technological end use in the classroom typically helps to deliver learning materials and support student learning (Cheung, 2013). According to Cheung's description and those by Gasson and Haden (2014), users of computer-adaptive programs appear to be end users, simply consuming the lessons that are delivered to them. With this in mind, it would be important to know if the students' technology end-user status affects communication and relationships between students and teachers.

To transition students beyond mere end users of technology and allow them to develop more sophisticated skills, many education leaders are embracing policies that develop 21st-century learners. Twenty-first-century learning uses modern technology to create the educational environments that can reflect the ideals that American education pioneer John Dewey long envisioned (Hursh, 2008). These are learning environments where student information is obtained from experience, processed, and reflected upon; where subject specific disciplines are blended in project and inquiry-based learning situations in real-world contexts. Education in these environments embraces the social and communication components of learning as essential to the formulation of ideas and production of democratic citizens. The Partnership for 21st Century Learning (2017) has identified the following primary skill domains that are important for students to develop to be prepared for the complex life and work environments of the 21st century: creativity, critical thinking, communication, and collaboration. Widely available and immediate access to the internet allows 21st-century learners to use modern technology in blended or virtual environments to obtain, process, and communicate information (Hunsinger-Hoff, 2016).

While collaboration and communication are pillars of 21st-century learning, a recognized component is also the pursuance of personalization by allowing students to guide their educational trajectory, separate from their classmates. A personalized learning environment recognizes that objectives and content, as well as methods and pace, may all vary with each student. With a 21st-century learning springboard, personalized learning has gained significant momentum in modern educational practices, and technology-enhanced personalized learning (TEPL) environments are now more available than ever. Michigan and Ohio have passed legislation guaranteeing students an opportunity for competency-based, personalized learning, and New Hampshire is initiating a sweeping high school redesign to utilize competency-based systems for student advancement (USDOE, 2017). The USDOE (2017) uses competency-based learning synonymously with personalized learning and describes it as

> Transitioning away from seat time, in favor of a structure that creates flexibility, allows students to progress as they demonstrate mastery of academic content, regardless of time, place, or pace of learning… By enabling students to master skills at their own pace, competency-based learning systems help to save both time and money (p.1).

Personalized learning is more practical and popular with the increase of computer use and personalizing software, as it allows students to operate at their own pace and communicate with their own computer-adaptive learning programs (Roberts-Mahoney, 2015). Educators should be cautious when any mode of learning has the potential to isolate students and impacts the common learning in the social space of the public sphere. It should be recognized that student interactions with computer-adaptive learning programs fill a social space that was previously occupied with human social interaction in the classroom (Redding, 2013).

Redding (2013) suggests that a healthy classroom culture is a foundation on which students' feel a sense of belonging, a sense of being in a good place with good people. With a push for individualization, teachers cannot lose sight of the benefits of attachment to a group and interactions with other students in a whole-class environment, led by a skilled teacher (Redding, 2013). As Noddings (2015) postulates, “The main aim of education should be to produce competent, caring, loving, and lovable people” (p. 174). If Nodding’s statement is understood to be a moral aim for education, then it deserves attention in an educational landscape with increasing numbers of automated and faceless learning encounters. Positive student-teacher relationships are undoubtedly important to the academic, social, and emotional well-being of students (Birch & Ladd, 1997; Carlisle, 2011: Hamre & Pianta, 2001). It is important to understand if CAI programs, with student progress updates, suggestions, and accompanying restructured teacher role, strengthen student-teacher relationships with better information and more one-to-one student-teacher interaction. It is equally important to understand how the use of these programs affects the social aspects of learning and the ways in which teacher and students can communicate and interact within the learning environment.

Human-Robot Interaction

Since this study involves interactions between humans and machines, research into human-robot interaction is justified. The word *robot* has fluctuated in meaning over the past century, but a common conception of a robot is a machine that performs autonomous operations (Merriam-Webster, 2017). Robot has been used to describe assembly line machines, remote-controlled cars, self-roving vacuum cleaners, and even mobile phones. With this wide range of examples of robots, adaptive learning programs can certainly be considered robots with their ability to perform tasks, self-adjust, and communicate with students. Jack Fierrea, founder, and CEO of Knewton, a popular learning analytics software development company and provider of computer-adaptive learning systems, has remarked about his adaptive programs, “A good tutor can crack jokes and make you want to learn, but this robot tutor can essentially read your mind” (as cited in Lapowsky, 2015, p. 1).

Robots vary in the amount that they interact with humans: some merely exist in a common space with people, and others are specifically designed to be social companions. Even robots that are not designed to communicate with people, such as self-roving vacuum cleaners, become objects of attachment for humans (Sung, Guo, Grinter, & Christenson, 2007). This supports the notion that people tend to anthropomorphize everything within their environment, including social or non-social robots (Dautenhahn, 2007). Some robots are specifically designed to engage in social interactions with humans. Bartneck and Forlizzi (2004) define a social robot as an autonomous or at least semi-autonomous robot that is capable of following expected behavioral norms to interact and communicate with humans. According to Zhao (2006), social robots are designed to be interactive and autonomous and can exist in a mechanical or digital form. Robots have been designed to socialize with children for extended periods of time, whether it be to educate children about diabetes while they are in a hospital or for therapeutic communication with autistic children (Looge, 2016). A push has been made to focus on robots as social companions with research and design of robots to specifically focus on the interaction between humans and social robots (Mikloki & Gacsi, 2012). Research in the field of human-robot interaction (HRI) has primarily focused on the machines and how they can interact with humans, more so than child-robot interaction’s effects on children's relationships with other humans (Belpaeme, Baxter, Read, Wood, Cuayáhuitl, Kiefer…Looije, 2012).

The Watson computing system, designed by IBM, is being used by multiple vendors to personalize learning in a range of educational environments. The global education company, Pearson, is using the Watson system to pilot versions of interactive textbooks and an automated tutor. The system has students interact with the intelligent tutor through the computer screen (Coughlan, 2016). This robot-assistant will ask questions and give feedback and assistance by providing a social interaction that was previously shared with a teacher or peer. In 2016, a postgraduate course at Georgia Tech used a computer-adaptive teaching assistant named "Jill Watson" to answer questions and provide help in online forums. Students reported that the tutor could provide feedback and answer questions much more efficiently than other tutors. Yet these students were unaware that the tutor was not a human, but a virtual tutor powered by the artificial intelligence of IBM's Watson (Coughlan, 2016). The fact that these students were not aware of the non-human nature of their educational assistant, yet could engage in useful communication with it, shows how educational communication can stealthily shift from human-human to human-robot.

Classroom Environment

The environment within a classroom is critical to the quality of school life and learning. To gain a complete picture of what is happening in schools requires looking at more than academic achievement. Positive, measurable outcomes of student achievement are primary goals of many educational institutions, but classroom environment is a potent factor in those outcomes (Fraser, 1986).

Classroom environment, sometimes referred to as classroom climate or learning environment, can be broadly defined as the quality of the setting in which students learn. It is a dynamic state comprised of many interconnected and substantial components including physical, organizational, and social variables (Adelman & Taylor, 2005). The environment of a classroom can fluctuate over time ranging from dysfunctional to supportive, and a supportive or positive classroom environment is fundamental to effective education in schools (Adelman & Taylor, 2005). It is well documented that classroom environment influences student achievement (Arter, 1989; Fraser & Walberg, 1991; Thapa et al., 2013). Classroom environment has been shown to affect student learning, behavior, self'-efficacy, engagement, and socio-emotional health (Fraser, 1998; Freiberg, 1999).

Moos (1979) outlined three dimensions of human environments that can be applied to classroom environments: relationships, personal development, and systems maintenance and change. The relationship dimension refers to the nature and magnitude of personal relationships, including how people are involved in the environment and support one another. The personal development dimension encompasses the activities undertaken for individuals to grow personally and enhance their own well-being. The dimension of system maintenance and change refers to the characteristics of the environment related to orderliness, clarity of expectations, and responsiveness to change.

These three dimensions can be used to frame the structure of positive learning environments.

As relationships are foundational to human environments, student-teacher relationships are foundational to establishing and maintaining positive classroom environments. Effective teachers can manage the environment and facilitate the flow of learning by quickly assessing and acting upon the cognitive and behavioral needs of students (Hattie, 2012). The student-teacher relationship is fundamental to the classroom environment and, more importantly, fundamental to the academic success and well-being of each student within the class (Hamre & Pianta, 2006). Likewise, student-teacher relationships are documented as important factors to school outcomes (Finn, 1993; Marks, 2000).

With an understanding of the importance of student-teacher relationships on academic, social, and emotional outcomes, further literature review explores factors that contribute to those student-teacher relationships and how the presence of CAI programs may affect those relationships. Further examination of research lays the groundwork for further study into potential barriers or supports for effective student-teacher relationships and new trends that potentially challenge the primacy of the student-teacher relationship within the classroom environment.

Technology Enhanced Personalized Learning

The concept of personalized learning stems from the fundamental ideas of individualization and differentiation. Individualization, in a progression toward mastery learning, matches the pace and instruction with the unique needs of each student (Bloom, 1971). Similarly, differentiated instruction is adapted to suit the interests and abilities of different groups of learners within a classroom (Tomlinson, Brimijoin, & Narvaez, 2008). Technology-enhanced personalized learning (TEPL) is based on the recognition that individual students learn in different ways and at different rates; therefore, information should be presented in different ways to reach everyone best. The USDOE (2010) defines personalization as

> Instruction that is paced to learning needs, tailored to learning preferences, and tailored to the specific interests of different learners. In an environment that is fully personalized, the learning objectives and content, as well as the method and pace, may all vary. (p.12)

Along with this definition is the notion that personalization links instruction to student needs and interests, thereby contributing to students' self-direction, enhancing motivation to learn and learning itself (Redding, 2013).

According to the USDOE (2017) website, personalized learning is synonymous with competency-based learning where students progress through the curriculum by showing mastery of academic content, as opposed to progressing from grade to grade based on classroom seat time. It is important to note that the USDOE website also states that by enabling self-paced skill mastery, competency-based learning programs save time and money by increasing efficiency and productivity. These purported benefits can result from personalized systems that utilize staffing patterns differently, present multiple pathways to graduation, leverage technology more effectively, allow for 24/7 access to learning, and help identify interventions to meet the needs of students best. Personalized instruction is charged with adapting content and learning objectives along with method and pace while remaining focused on the relevant content standards (USDOE, 2017). For decades, educators have struggled with the tension between personalizing learning for each student and covering mandated curriculum requirements with entire classes. Given typical class sizes and content standards requirements, more often than not the classroom focus trends toward completing the required curriculum en masse, at the expense of true personalization (Kapp, 2017). Customizing instruction to meet the needs of each student in the classroom has shown to be extremely time consuming and commonly unrealistic without the help of technology (Bienkowski, Feng, & Means, 2012; Krüger, Merceron, & Wolf, 2010). Luckily for supporters of technology-enhanced personalized learning, advancements in learning analytics can increase teacher's abilities to support personalized learning (Atkenson & Will, 2014; Christensen, Horn, & Johnson, 2011).

Computer-Adaptive Instruction

With increasing sophistication and rapid advances in analytic and computer technology, schools can more readily implement computer-assisted, personalized learning (Hwang, 2002; Tsai, 2004; Kapp, 2016). Digital adaptive learning tools have been defined as, "Education technologies that can respond to a student's interactions in real-time by automatically providing the student with individual support" (EdSurge, 2016, p. 15). Computer-adaptive instruction programs collect and analyze massive amounts of student data to create a personal learning pathway for each student. Learning analytics systems use models to determine when a student is ready to progress to the next topic, if a student is at risk of failure, and what future course will best suit each student

(Bienkowski, Feng, & Means, 2012). Computer-adaptive instruction programs are increasingly popular in tech-enabled classrooms and online learning environments as a way to deliver content and assess mastery. An industry leader in learning analytics, Knewton, gathers hundreds of thousands of student-data points each day and uses this information to personally adapt learning to each student (Cator & Adams, 2013). As students provide program input through clicks, strokes, and type, algorithms process the masses of student data to determine the appropriate next lesson for each student.

Sophisticated analytic technology has been used in commercial fields to process extensive data sources, identify patterns in the data, and use the patterns to aid in decision-making (Papamitsiou & Economides, 2014). The term "big data" is used to describe data sets too large for typical systems to obtain, store, process, and analyze. Instead, computer algorithms process these large databases, generate information and make decisions regarding the data (Manyika, Chui, Brown, Bughin, Dobbs, Roxburgh, & Byers, 2011). Businesses have referred to their personalization efforts as a pursuit for the "Market of One," which provides a level of customization and service that allows clients and shoppers to feel as though they are exclusive or preferred customers. For example, Amazon specifically markets to individuals and makes product recommendations based on a customer's previous activity combined with statistics from preferences of other customers (Wolf, 2010).

Research and development departments in the education industry transferred the principles of analytics for personalization from the business world to gain insight from students' activities. Two specific areas, Educational data mining (EDM) and Learning

Analytics (LA) are differentiated within the big-data-based field of personalized learning. Educational data mining refers to the research, development, and application of computerized methods to find patterns in large collections of educational data that would otherwise be difficult or impossible to analyze due to the massive volume of data within which they exist (Romero & Ventura, 2013). Learning analytics can be derived from applications of EDM and was defined at the 1st International Conference on Learning Analytics and Knowledge (2011) as "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes for understanding and optimizing learning and environments in which it occurs" (TEKRI, p. 1)

Programs using EDM techniques employ a variety of modeling techniques including clustering, fuzzy logic, genetic algorithms, and inductive reasoning to analyze student responses and identify learning behavior patterns. To do so, the programs classify students into groups, make predictions about outcomes, and plan for those outcomes. Students are classified based on academic achievement, exhibition of irregular behaviors, and system navigation and usage (Castro, Vellido, Nebot, & Mugica, 2007).

The edtech industry has yet to settle on common language around the types of modern adaptive systems. Pugliese (2016) has offered four main categories in which adaptive programs can be categorized: rules-based, decision tree, advanced algorithm, and machine-learning-based adaptive systems. While these types of adaptive systems have means to personalize instruction for students, each system is unique in its adaptive methods and capacity for personalization.

Rules-based (RB) adaptive systems are built upon predetermined sets of rules that delineate specific learning pathways for all students to follow without collecting learner profile information or learning characteristics. These types of systems do not specifically adapt to an individual learner but rather allow for students to progress through lessons at their own pace and receive automated feedback along the way. Self-paced learners can utilize RB systems to work through a linear sequence of lessons, frequently taking diagnostic assessments to determine if they are ready to progress or are in need of more instruction or practice. Instructional methods are not altered as students move through the lessons unless a teacher manually alters the program or intervenes (Pugliese, 2016). Since complex analytics are not required for this type of adaptive system, teachers and districts can build their own RB systems through teacher-created instructional videos and persistent online formative assessments via a learning management system such as Google Classroom, Schoology, or Blackboard. While RB systems are the least technologically advanced adaptive systems, they are able to provide teachers with more control over which lessons students access at any given time.

Decision tree (DT) adaptive systems are similar to RB systems in that they operate on predetermined rules and do not incorporate learner profiles or individual learning characteristics, but rather use a tree system of limited binary assessment items. As students progress through lessons and take assessments, DT systems utilize *if this, then that* sequences to track each student onto a prescribed learning path. Pre-set units of content material and assessment banks are used to guide students through content (Pugliese, 2016).

A more sophisticated form of adaptive system is an advanced algorithm (AA) system which collects data on each student who uses the system and compares that to data from other students. In doing so, a learner profile is created for each student based on their calculated mastery of each topic. In order to personalize instruction, AA systems collect and analyze large amounts of data including transactional behaviors such as clickstreams, time intervals, and attempted assessments to determine the most appropriate learning pathway for each student. These learning pathways are altered in real time as the analytics calculate an optimal workflow based on the student's learning profile and data from other students who have struggled or succeeded with similar concepts (Pugliese, 2016). While AA systems are more complex in nature, the analytics being used do not permit teachers to alter the content or assessments in the ways that RB and DT systems allow.

The most sophisticated adaptive systems currently available are categorized as machine-learning-based adaptive systems. Machine learning (ML) is not a new concept, but the applications utilizing big data and predictive analytics are more advanced than ever before. Similar to AA adaptive systems, ML systems create learner profiles based upon student responses and interactions with the program, but ML profiles also take into account demographic information, learning preferences, and academic strengths and weaknesses. Learning analytics are continuously used to adjust instruction and make predictions about students' level of mastery of any given topic. What also sets ML apart from other adaptive programs is the ability of the program to assess how a student learns and adjust how the content is delivered. The type of content that one student experiences may be different from the type of content that any another student experiences, based on the strengths and needs that have been determined through the learning analytics. Programs such as ALEKS and those developed by Knewton are examples of ML. With ML systems, instructional methods continue to improve over time based on the billions of data bits that are analyzed in real time (Pugliese, 2016).

Despite the wide range of adaptive system types and modern advances in CAI, no current systems have synchronous capabilities to link students to each other or create communities of learners. Social interaction is a crucial element in the measurement of both cognition and engagement and should be considered an essential element of an adaptive course. Personalized learning should be seen as a piece of a larger educational picture where students collaborate in teams and share resources (Pugliese, 2016).

The use of analytics in education continues to grow due to increasing student data quantity and quality in addition to advances in computing and analytic tools. The learning sciences can be considered late in adopting analytics when compared to other sciences. *Computers in Biology and Medicine*, the first journal to specifically focus on analytics used in biological sciences, ran its first issue in 1970 compared with the 2009 publication of the first journal of its type in the education field, the *Journal of Education Data Mining* (Baker, 2006).

According to the United States Department of Education's Office of Educational Technology (2012), computerized learning modules enable systematic and real-time student assessment. By collecting and mining student data from local assessments and nationwide databases, learning analytic software can generate immediate feedback regarding student performance for both students and teachers. Through further analysis of student data patterns, analytic software can predict individual student outcomes such as failure, need for assistance, or readiness to advance and identify pedagogic strategies that statistically match the student's profile (USDOE, 2012). The learning analytics utilizing the data gained from students using computer-adaptive learning programs has diagnostic and predictive capabilities that educators can use to identify the most successful resource or strategy for any given student (West, 2012). An assumed advantage of these “big data” based analytics are that the feedback and guidance provided by the program are faster and more efficient than conventional school assessments. This efficiency is noted in the teacher’s time saved from scoring student work, and the immediacy of the feedback to the student from a computerized program (West, 2012).

As students progress through online lessons, they are guided by built-in tutorials, digital media, and assessment feedback (Roberts-Mahoney, 2015). The assessment process is ongoing and even referred to as stealth assessment because neither the teachers nor the students using the programs are aware of every bit of information that is being saved and analyzed by student interactions with the program (DiCerbo & Behrens, 2014; Baker & Inventado, 2014).

Computer adaptive instruction programs have been referred to as intelligent tutoring systems, because of their ability to issue feedback to students, prioritize lesson sequences, and provide remedial instruction or advancement when needed (Leong, 2013; Mendicino, Razzaq, & Heffernan, 2009). Replacing teaching and assessment functions traditionally done by classroom teachers, some CAI programs are even designed to imitate human tutors through interactive features using dialogue and immediate feedback (Bennett-Smailis, 2016; Mendicino et al., 2009). The concept of an adaptive tutor is not new and can be traced back to Sidney Pressey's teaching machine developed in the 1920's. Pressey's teaching machines were used by students to answer multiple choice questions. If the student answered correctly, they advanced to the next question, and if they answered incorrectly, the mistake was noted and the student continued answering until the correct choice was made. Pressey advocated that his teaching machines made teaching and learning more efficient because students would not need to wait hours or days to receive feedback on an assessment. This immediate feedback provided by the machine was akin to a one-to-one tutor (Roberts-Mahoney, 2015). Skinner (1958) also supported the use of teaching machines, explaining that their ability to reinforce small units of desired behavior provided an educational benefit.

Similar to the original learning machines, it is important to recognize the type of information that is being communicated and assessed through computer-adapted learning programs. Many of the programs focus on student acquisition of discrete skills that can easily be recorded and processed from a comprehensive database (Roberts-Mahoney, 2015). Thus, learning is reduced to small components to be analyzed by software to personalize learning for the student (Bienkowski et al., 2012). Educators who utilize these adaptive learning programs should be cognizant of the fragmented competency-based structure that the programs utilize. They cannot portray a complete picture of the student's learning, nor can they address complex needs that exist outside of the program structure (Roberts-Mahoney, 2015).

Proponents of adaptive learning programs point to a personalized student learning experience with self-controlled pacing, content, and environment. Also, these proponents say that the possibilities for differentiation and personalization allow teachers to connect on a deeper level with students because they know their strengths and needs in a more detailed way (Lemke, 2013). This form of personalized learning, however, does not actually use human decision-making to personalize the learning. Instead, algorithms written by data scientists control the pacing and content instead of the students and teachers. Critics of these adaptive systems argue that computerized learning is no more than a behaviorist approach to acute skill building which risks removing students from essential social interaction within the learning environment (McRae, 2010). Despite the ability of these programs to tailor learning situations to each student, they ultimately adapt the educational environment, albeit a virtual environment, to produce the desired behavior of the student (Kohn, 2015).

For personalized learning to be effective, teachers need to be aware of the attributes, needs, and resources of their students (Redding, 2013). With curriculum decisions and instructional practices being reduced to algorithms to personalize learning, the decision making can be taken away from the teacher. Teachers can make fewer pedagogical decisions beyond assisting students with problems initiated by the program; rather, they manage the technology that makes the decisions for them (Roberts-Mahoney, 2015).

Proponents of personalized learning have long suggested that teachers should shift from the role of an actual "teacher of knowledge" to a "guide" for students to create their own knowledge. In reference to teaching, assessment, and planning, claims have been made that technology can do the work more accurately and efficiently than humans (Macfayden & Dawson, 2009; Shechtman, DeBarger, Dornsife, Rosier, & Yarnall, 2013). With technology handling the teaching and assessment, teachers manage the technology by assigning it to students and ensuring student compliance in the classroom so that programs can make the most effective decisions for student learning (Frame, 2013).

This form of personalized learning, education via adaptive learning programs, not only shifts the role of the teacher to that of a guide, it can also remove the teacher from the learning environment. As students complete their work online, error messages are sent when needed, and hints can be provided when requested. This automated feedback can redirect the student without the need for social interaction with the teacher (West, 2012).

Student-Teacher Relationships

Children need positive relationships with adults to help them develop socially and emotionally (Hamre & Pianta, 2001). Their interpersonal relationships strongly influence the socio-emotional health and motivation of adolescents. When children enter school, their non-parental adult relationships become increasingly important to foster a healthy adjustment to school (Birch & Ladd, 1997; Greenberg, Speltz, & Deklyen, 1993; Howes, Hamilton, & Matheson, 1994). As children develop from childhood to adulthood, they experience rapid social, emotional, physical, and cognitive changes (Hamre & Pianta, 2001). During this timeframe, adolescents are increasingly influenced by their peers over adults. Through this important time, during the waning of children's relationships with adults, teachers need to connect with students to build positive interpersonal relationships purposefully. Healthy relationships with teachers can help adolescent students transition both socially and emotionally (Carlisle, 2011). The adult support provided in positive student-teacher relationships can be vital during a time when adolescents are creating their own identities and refocusing their attention away from their parents as primary role models (Wigfield, Lutz, & Wagner, 2005).

It is important to note that this transitional time for adolescents is also when students move from elementary through middle school and into high school. School structures can vary drastically in each phase, and classroom environments have marked differences as well. These differences are compounded by the changing interpersonal relationships that adolescents experience (Wigfield et al., 2005). For example, students report that quality time with teachers decreases during the middle school years (Lynch & Ciocchetti, 1997). These are the years when students need to maintain positive child-adult relationships to develop healthy academic, social and emotional habits. Through relationships with students, teachers can provide social support to improve overall classroom and life satisfaction for everyone. Students need a positive relationship with their teachers through these transformational periods of personal development (Danielsen, Samdal, Hetland, & Wold, 2009).

The term positive student-teacher relationship is utilized in a variety of contexts and lacks a pinpointed definition. Across the literature, there is no consistent assignment of characteristics that define positive student-teacher relationships (Britt, 2005). Multiple research tools exist to study the nature of student-teacher relationships with many measuring different components or effects of the relationships. Without a commonly accepted definition of student-teacher relationships, it is difficult to identify any single component as most critical to them being healthy and effective. Research has tied teacher characteristics of effective leadership, helpfulness, and friendliness to positive student-teacher relationships (Wubbels & Brekelmans, 2005). Positive student-teacher relationships have been explained by student perceptions of feeling supported, respected, and valued by educators (Doll et al., 2004).

Student-teacher relationships have been described by Pianta, Steinberg, and Rollins (1995) as consisting of varying levels of closeness, conflict, and dependency. A high degree of closeness involves kind interactions and open communication. Disagreement and negativity represent high levels of conflict. High dependency involves a student's over-reliance on the teacher (Hamre & Pianta, 2001). Closeness, conflict, and dependency have been descriptors in many studies on student-teacher relationships (Doumen et al., 2012; Pianta, 2001). These factors are important variables to the academic and socio-emotional well-being of students in elementary school (Baker, 2006).

Trends in educational research show several other key areas to consider for a holistic definition of positive student-teacher relationships. The level of academic and socio-emotional support from the teacher is often cited (Murdock, 1999). Perceived level of caring is used to describe student-teacher relationship quality (Teven & McCrosky, 1997). Ultimately, teacher behaviors will dictate the style of student-teacher relationships and the potential results of those relationships.

These ideas of positive student-teacher relationships are in line with Attachment Theory (Bowlby, 1988) and the need for not only young students but students from kindergarten through twelfth grade, to have a secure attachment to teachers in their lives. Throughout middle childhood and adolescence, the availability of an attachment figure continues to be important to student development. This availability includes a physical presence, responsive communication, and awareness of the needs of each student (Bergin & Bergin, 2009). It is possible that some teachers and school structures do not present the opportunity to attach and this may be the case in CAI settings due to the potential displacement of student-teacher interactions by student-program interactions. In school settings that exhibit the characteristics of secure attachment, communications are clearly acknowledged by the attachment figure (Parker, Rose, & Gilbert, 2016).

Academic support is fundamental to the student-teacher relationship. Documented teacher behaviors and student perceptions of support are used to describe the level of academic support in classrooms (Hughs et al., 2008). A positive student-teacher relationship assumes academic achievement as a goal. A teacher positioned in close proximity to students with a high degree of influence displays awareness, leadership, and an ability to orchestrate learning, all of which contribute to effective student-teacher relationships (Wubbels & Brekelmans, 2005). Other dimensions of the student-teacher relationship related to socio-emotional and psychosocial contexts can affect a student's well-being and ultimately affect academics (Dorman, 2002).

The socio-emotional support of a student-teacher relationship is important to a student's overall well-being and academic engagement. This support can be characterized as a caring relationship. Students have shown to benefit both academically and socially when they perceive their teachers as caring (Elder, Johnson, & Crosnoe, 2004). Elder et al. (2004) studied students (n = 10,991) in 126 secondary schools and determined that perceptions of strong student-teacher bonds were positively related to student achievement (b = .05, $p < .001$) and negatively related to disciplinary issues (b = -.05, $p < .001$). These findings were obtained from research based on data from the National Longitudinal Study of Adolescent Health, which began in 1994. Once a perception of a secure relationship has been established for students, they can be open to learning about socially appropriate behaviors and how to achieve them (Gallagher, 2013). When teachers provide social support and have high expectations, students have shown higher levels of engagement (Marks, 2000). Hamre and Pianta (2001) explain socio-emotional support as a presence of positivity, closeness, and warmth. By exemplifying these characteristics, teachers can lay a relationship foundation that enables students to feel comfortable assuming risks necessary to meet academic and social challenges.

Leitao and Waugh (2007) analyzed teacher survey responses (N = 139) regarding student-teacher relationships and identified three key social and emotional aspects of those relationships: connectedness, availability and communication skills. Leitao and Waugh expanded on the notion of teacher-availability to students, outlining attributes the teacher may demonstrate. These attributes include the teachers' ability to communicate availability, make time for availability through small groups or one-on-one, make time with students a priority, be approachable, and be able to follow up with students (Leitao & Waugh, 2007).

Teachers have managed to find ways to remain connected with their students in the presence of technology (Burns, 2003). The use of text dialogue, discussion threads, and digital feedback have been used to keep teachers and students connected. A relationship with a computer-adaptive tutor, however, is distinctly different from any computer-mediated human-human relationship, such as that of the student and teacher.

Many of the factors that contribute to positive student-teacher relationships can be classified as immediacy behaviors (Frymier, & Houser, 2000). Immediacy is a perception of closeness between people and is a variable in student motivation and affect toward learning. Teachers can display immediacy by various verbal and non-verbal actions (Richmond, Gorham, & McCroskey, 1987). Verbal and non-verbal immediacy have been shown to affect student motivation and affect toward learning (Frymier, 1994). Verbal immediacy includes teachers calling students by name and asking students to share opinions and information about themselves. Nonverbal immediacy is displayed though teacher eye contact, vocal expressiveness, teacher movement, relaxed posture, and smiling (Frymier & Houser, 2000). Frymier and Houser conducted a study to determine student perceptions of the importance of communication skills and immediacy behaviors. This study (N = 93) directed university students to indicate how important eight communication skills and immediacy behaviors were to good teaching. The skills and behaviors include referential skill, ego support, conflict management, regulative skill, verbal immediacy, conversational skill, nonverbal immediacy, narrative skill, persuasion, and comforting. Communication skills were measured with the Burleson and Samter's Communication Function Questionnaire (1990) and immediacy perceptions were communicated then analyzed based on Richmond, Gorham, and McCroskey's (1987) nonverbal immediacy scale and Gorham's (1988) verbal immediacy scale. A seven-point Likert scale ranging from "very important" to "very unimportant" was used. Results showed that all of the communication skills and immediacy behaviors, except for comforting, had means above the mid-point of 4.0. These results indicate that students feel that communication skills and both verbal and non-verbal immediacy behaviors are more important than not important to good teaching. T-test results were reported in order as follows: Referential skill was reportedly more important than ego support, $t(92) = 6.85$, $p < .001$. Ego support was more important than conflict management, $t(92) = 4.68$, $p < .001$. Conversational skill was shown to be more important than nonverbal immediacy, $t(92) = 5.61$, $p < .001$, yet nonverbal immediacy was significantly more important than narrative skill, $t(92) = 3.23$, $p <.01$. Lastly, persuasion was significantly more important than comforting, $t(92) = 4.90$, $p < .001$.

Teacher immediacy has been shown to have a positive correlation effect on cognitive learning (Richmond, Gorham, & McCroskey, 1987). However, when taken collectively, research on the cognitive effects of teacher immediacy remains inconclusive. A meta-analysis of 71 teacher immediacy studies conducted before 2004 indicated significant impact on student affect and perceptions but a modest effect on cognitive learning (Witt, Wheeless, & Allen, 2004). It can be argued that effects of immediacy in student-teacher relationships ultimately affect the classroom environment which, in conjunction with the other variables previously mentioned, can lead to improved academic outcomes.

Student-Teacher Relationship Measurement

In an effort to determine criteria that are most vital to student-teacher relationships, quantitative relationship measurement scales can be examined. The Questionnaire on Teacher Interaction (QTI) is a tool used to collect student and teacher perceptions of student-teacher relationships and consists of 64 questions for students to rate their teachers or teachers to rate themselves on a five-point Likert scale (Wubbels & Levy, 1991). Data gained from the QTI is divided into eight scales that correspond with the following eight teacher behavior types: leading, helpful/friendly, understanding, student responsibility/freedom, uncertain, dissatisfied, admonishing, and strict. The eight behavior types are functions of Leary's (1957) two-scaled model for interactional behavior, influence, and proximity, which are set on independent vector axes and analyzed in relation to one another (Wubbels & Brekelmans, 2005).

The Model for Interpersonal Teacher Behavior (MITB) uses student-generated data collected from the QTI to analyze student perceptions of their relationships with teachers. The MITB defines teacher behavior in the same dimensions as the QTI, influence, and proximity. The level of teacher influence ranges from submission to dominance, while teacher proximity ranges from opposition to cooperation. Depending on the levels of influence and proximity, the following eight types of teacher behavior can be identified: leading, helpful/friendly, understanding, student responsibility and freedom, uncertain, dissatisfied, admonishing, and strict (Wubbels & Brekelmans, 2005).

According to Wubbels and Brekelmans (2005), effective student-teacher relationships correlate with high degrees of teacher influence and high degrees of teacher proximity. Utilizing the MITB, high influence and proximity are characterized by leadership, helping, and friendliness. Typically observed behaviors of teachers operating in this preferred category are characterized by a mixture of the following attributes:

Leadership

- Is aware of what's happening
- Organizes and leads
- Gives orders and sets tasks
- Structures classroom situations

Helping/Friendly

- Shows interest and assists
- Behaves in a friendly and considerate manner
- Can make a joke
- Inspires confidence and trust
- Explains information and holds the attention of students

Based on the findings of Wubbels and Brekelmans (2005), school leaders looking to improve the climates and relationships inside their buildings can use the MITB to see if and where these key attributes are occurring and create structures to support attribute development where needed. Teachers wanting to improve their relationships with students can exemplify a blend of leadership, helping, and friendly attributes to foster positive student-teacher relationships.

The Teacher-Student Relationship Inventory (TSRI) is a more simplified, 14-item, measurement tool that can also be employed to quantify relationship quality. The TSRI is a teacher self-reporting tool only used to assess self-perceptions of student-teacher relationship quality (Ang, 2005). A limitation of this assessment is that it does not account for student perceptions of their relationships with their teachers. Student perceptions have been shown to differ from the teacher's perceptions of the student-teacher relationship. Research suggests that sole reliance on teacher-reported perspectives provides an incomplete picture of student-teacher relationships (Hughs, 2011).

In conjunction with any student-teacher relationship measurement or descriptive tool, context must be considered. Each school exists in a unique community with unique circumstances and populations. Cultural traditions and expectations also play into school and classroom climates (Kelly & Barsade, 2001). These cultural factors affect student-teacher relationships and should be recognized and utilized by teachers to deepen relationships and foster school success. In addition to cultural narratives of teacher roles and expected student-teacher interactions, students' backgrounds and life experiences shape relational schemas that are brought into the classroom. Students arrive with preconceived ideas of social relationships that can affect students' interpretations of teacher interactions (Davis, 2003). Studies of student-teacher relationships that do not account for these background factors should recognize that their omission from analyses are research limitations.

Teacher Role

Stemming from the research on student-teacher relationships, teacher role assumes the characteristics of teachers in their relationships with students. These characteristics range from caring to proximity to support. A teacher's role can range from a leader in the classroom who leads instruction or supports student learning through exploration to a teacher who follows a prescribed program and assigns students to adaptive programs accordingly. To describe teacher role, definitions of philosophical orientations to learning help ground the beliefs and intentions of educators in their role as a teacher.

Behaviorist approach. A teacher or learning organization may trend toward behaviorist beliefs where learning is a result of knowledge being transmitted to students. In the behaviorist orientation, everything can be taught, and learning is a result of teaching that conveys information for student consumption (Skinner, 1958). As such, a teacher's role becomes one that provides or assigns essential instruction and support for students to comprehend required information. Behaviorist approaches to learning have been mainstays throughout the history of American education, and they support the logistics of delivering specific and sequential standards-based information to students.

A behaviorist approach to learning can lend itself to what is known as a *teacher-centered* approach; an approach in which the teacher is a classroom leader who directs student learning by imparting expert knowledge through teaching and assigning specific lessons or activities (Edglossary.org, 2014). This approach offers a predictable system that many teachers appreciate for its creation of order around a central well-defined teacher role (Christenson, 2013). In a computer-adaptive classroom, a teacher-centered approach can shift toward a program-centered approach; an approach in which the program directs the student learning.

Constructivist approach. In contrast to behaviorism, constructivism is the philosophical orientation that views student learning as constructs derived from experiences with content and society (Dewey, 1925). In this orientation, a teacher's role is to ensure students receive the experiences, social interaction, and support necessary to learn by building concepts around experiences. The social constructivist orientation situates teachers as participants and guides in a social process of learning through interaction and communication around shared learning experiences (Vygotsky, 1978). Teachers may embrace a social constructivist philosophy in theory and partial practice, and also employ behaviorist strategies by leading or assigning input-output computer-adaptive lessons.

A constructivist approach to learning supports what is known as a *student-centered* approach. A student-centered approach to learning typically involves more student input, choice, and discussion in learning experiences (Edglossary.org, 2014). Essentially, through student-centered instruction, students are able to explore content as teachers act as guides to support learning (Peters, 2010).

Balanced and shifting approaches. Educators may employ behaviorist teaching strategies for some lessons and embrace a more constructivist approach to tackle other concepts. Likewise, student-centered and teacher-centered instruction are not a dichotomy, rather a continuum of instructional behaviors and beliefs (Kollmer, 2013). In a study of ($N = 301$) of administrators, teacher, students, and parents as stakeholders in one-to-one classroom computer initiatives, a teacher role-shift was noted as the classroom environment moved from teacher-centered toward student-centered. Teachers reported that the technology helped them to differentiate curriculum and instruction, allowing students to work on different content at different levels (Fairman, 2004).

In a content analysis of 12 documents including USDOE reports, studies on learning analytics, and personalized-learning advocacy documents, Roberts-Mahoney (2014) identified an education-technology industry call for a teacher role shift through personalized learning in K-12 education. Documents were examined to determine the extent to which big data, learning analytics, and personalized learning are extending the privatization of public education. Results of the analysis revealed that the role of the teacher in data-driven personalized-learning environments is minimized with regard to curricular, instructional, and assessment decisions, with favor given to decision-making via algorithms. These findings reveal a change in the conception of teaching, positioning teachers' roles as coaches or guides, secondary to non-educators. Teacher role also shifts in ways to include more data use, with potential benefits dependent on a company's algorithms and instructional path. While personalized learning purports every student is on their own learning trajectory, learning is not student-centered as the adaptive-programs are a controlled environment with technology steering at every decision point (Roberts-Mahoney, 2015).

Teacher role varies within and among classrooms depending on a variety of factors from teacher and school educational philosophy to available technology resources and adherence to standards. Adams (2017) has identified seven distinct roles that a teacher may assume in modern classrooms. It should be noted that teachers may not limit themselves to any one role, but the following distinctions can be helpful in clarifying the complexities of various teacher roles.

Controller. The teacher as a controller assumes a position where they are in complete charge of the class, dictating what students will say and do. This position can align with behaviorist approaches as reproduction and drilling techniques are used.

Prompter. When the teacher is a prompter, they encourage student participation and make suggestions as to how students may proceed in their learning. In this role, teachers only help students when necessary.

Resource. A teacher may be a type of roving resource, ready to assist when needed. In this role, the teacher makes themselves available for student consultation only when necessary. Often, teachers will guide students in using online resources to support learning.

Assessor. In this role, the teacher assesses how students are performing or have performed. After the assessment, the teacher usually provides students with the feedback necessary to make corrections and continue learning. There is a wide variety of forms of assessment and feedback that can be used for any given learning situation.

Organizer. In this role, the teacher plans and gives instructions necessary for students to be successful in a variety of learning activities. This can include providing demonstrations as well as participating with students as they engage in learning. Lesson openings, feedback during, and lesson closings are also roles that are assumed by a teacher as an organizer.

Participant. The teacher as a participant takes part in learning activities with their students. Teachers in this role can potentially dominate an activity or can have an awareness to stand back and not be the center of attention.

Tutor. In this role, the teacher acts as a coach as students work through projects or engage in independent lessons. As a tutor, the teacher provides students with advice and guidance necessary for students to clarify ideas and perform tasks with success. This role also allows the teacher to interact with students on a one-on-one basis to provide individual assistance and support to meet unique student needs.

Teacher role has shown to shift with one-to-one computing (Fairman, 2004) and there is an expectation from private and public proponents of personalized instruction that teacher role is that of a facilitator or guide. In marketing their computer-adaptive learning technology to schools and businesses, industry leader IBM proclaims, “The teacher role changes to a higher value plane, with less focus on lesson creation/formal lecturing and an increasing focus on facilitating/coaching” (IBM, 2016, p. 12). These claims were not the reality revealed in a qualitative case-study by Lopez-Boren (2016), in which teachers who implemented computer-adaptive programs felt their position changed from a facilitator and companion in the learning process to a policing/authoritative position. In this study, four high school teachers described their experiences implementing one-to-one computing initiatives in Language Arts classrooms. It was shown that the teachers felt that their relationships with their students were changed as their teaching role shifted from a facilitator and companion in the learning process to a policing/authoritative position. The teachers in the study noted that students are savvy in navigating between websites and hiding the alternate activities that they are engaging in instead of the designated activity (Lopez-Boren, 2016).

Characteristics of traditional teacher roles are positioned to change with the implementation of computer-adaptive programs, fluctuating among a leader of direct-instruction to facilitating collaborative inquiry to an assigner of programs. The role of the teacher is intertwined with the nature of student-teacher relationships as relationship-factors such as proximity, communication, and support can be supported through teachers' actions in their role as a leader, instructor, or facilitator.

Summary

When computer-adaptive systems direct instruction, feedback, and learning flow, the student relationship with the artificial intelligence of the program increases in relation to that with the teacher. Research specifically analyzing student-teacher relationships under the influence of computer-adaptive learning programs is distinctly lacking. Studies have addressed relationship effects from increased technology, but the focus of this research has remained on human-to-human interaction mediated with technology (Lopez-Boren, 2016).

If teachers do not adapt their role to incorporate the best use of education technology, they risk being displaced by that technology. The USDOE's Office of Educational Technology (2017), clearly states that education technology allows teachers to be guides, facilitators, and motivators of learners rather than subject specialists who deliver instruction around content specific objectives. According to USDOE, teachers no longer need to be content experts across all possible subjects because so much information is readily available through the internet. Rather, teachers can become co-learners with their students and help students find and use the tools they need to learn.

According to Lopez-Boren (2016), technology in the classroom impacts the teacher's role and pedagogical perception of knowledge and learning. Thus, education leaders should be mindful throughout the implementation of any education technology program that the programs being used can have both positive and negative effects on the role of the teacher in the classroom and their views on teaching and learning. With more advanced technological applications, education technology can position a teacher in an uninhabitable space, possibly leading to marginalization or decentering of the teacher in their role as a leader and educator. Relationships between students and teachers change under one-to-one computing conditions and technology is capable reducing teachers' agency and taking some of the teachers' control over the focus of learning and what knowledge is being acquired (Lopez-Boren, 2016).

Without an understanding of the role shift required of teachers who integrate more advanced education technology such as CAI programs, school leaders risk disenfranchising the very people who are needed to maintain positive and healthy interpersonal relationships within the schools' walls. If teachers want to integrate CAI into their classrooms successfully, they not only must be willing to let students learn at their own pace, but they must also be comfortable letting software make vital decisions about what a student should learn next. Teachers must be willing to resign their old notions of a lecture or whole-class models and provide personalized instruction to wherever a student is at that moment (Edsurge, 2016).

Chapter Three: Methodology

The following chapter discusses the methodology used to conduct this study, which investigated the perceptions and experiences of teachers related to teacher role, communication, and student-teacher relationships through the implementation of CAI programs. A qualitative approach was used for this research because the perceptions of teachers' lived experiences were sought with the aim to identify enlightening participant responses and note themes that may be useful for teachers and education leaders who are considering or who have implemented CAI in schools. The researcher sought permission from the University of Portland Institutional Review Board, then from administrators and teachers in participating school districts, to interview and observe selected teachers who have used CAI programs with their students. Data sources, collection, and analysis are further explained in this chapter, as well as the role of the researcher.

Research Questions

As instruction in K-12 classrooms moves from teacher delivered to include more computer-driven lessons, attention should be paid to how these computer-mediated environments impact the relationships within the classroom. If some student-teacher interactions are replaced with personalized programs using interactive screens, and students communicate and build relationships with virtual tutors, it is important to know if the ability of the classroom teacher to connect with students is altered and how this change affects the classroom environment and accompanying social interactions. The purpose of this research, therefore, is to examine how teachers perceive their relationships with students and their role in classrooms where CAI programs have been introduced. The two following research questions helped guide this study:

1. How is teacher role impacted through the implementation of computer-adaptive instruction programs?
2. How do teachers perceive their student-teacher relationships through the implementation of computer-adaptive instruction programs?

Rationale for Methodology

A qualitative research design was chosen because this study sought to obtain teachers' perspectives on experiences within their classrooms and relationships with their students. Inductive analysis was performed because teachers' perceptions of these newly implemented technology programs were unknown, and this research sought to describe and examine the experiences currently taking place in classrooms. Merriam (2009) defines a basic qualitative study as one that involves people constructing an understanding of experiences with a phenomenon, the interpretations of the experiences, and the meaning created from the experiences.

This study was conceived in the social constructivist worldview. Constructivist research seeks to address the process of interaction among individuals (Creswell, 2014). The nature of social constructivism posits that individuals create subjective meaning from multiple and variable experiences. Social constructivist research hinges upon the perceptions of the participants and the ability of the researcher to elicit those perceptions. (Berger & Luckmann, 1966). This work sought to understand the elementary teachers' world and their work within that world. The researcher describes the unique and varied views of teachers to bring meaning to their experiences. This study examined teacher-student interactions as described by the teacher, with a focus on teacher role and relationships.

This study sought to uncover the meaning constructed by teachers around their role and student-teacher relationships throughout the phenomena of computer-adaptive learning program implementation. According to Spradley (1980), constructed meanings are expressed through language, both implicitly and explicitly. From that language expression, interpretivism can be used to bring understanding some complexities of meaning (Glense, 1999).

This qualitative research used interpretivism to examine the socially constructed and changing reality of the participating teachers. Glense (1999), posited that social realities are a construct of the participants in social settings. To better understand the nature of these constructed realities, "qualitative researchers interact and talk with participants about their perceptions…to seek out the variety of perspectives; they do not try to reduce the multiple interpretations to a norm" (p. 5). As such, the experiences and views expressed by the participants in this study were not only reduced to common themes; rather, attempts were made to highlight both common and unique perspectives to encompass the full scope of the experiences teachers encounter when adopting computer-adaptive learning programs.

To that end, interview data were collected and analyzed in hopes of gaining new perspectives on the implementation of CAI programs and how they can best be used or not used while supporting positive student-teacher relationships. Teacher interviews were followed up with classroom observations to obtain contextual information and confirm or expand upon the teachers' perceptions.

Participants and Setting

Purposive, criterion sampling was used to determine the participant teachers for this study. Per Creswell (2014), purposeful sampling should be used when a researcher desires to intentionally select individuals from which understanding around a central phenomenon can be built. For the purpose of this study, selection criteria limited participants to elementary teachers who participated in a K – 8 CAI pilot project sponsored by a state department of education. They used one of 16 identified CAI math programs in their classrooms during the 2016 – 2017 school year and use a CAI program in the current year. Elementary students, by the nature of their age and relative lack of educational experience, may be particularly susceptible to influences from computer-driven learning programs or opportunities to interact with content via a screen versus another human.

A focus on the perspectives of teachers who utilized CAI during the 2016 – 2017 school year ensured that participants had at least one year of experience with a modern CAI program in their classrooms. Participation in the state department of education pilot also ensured that the teachers in this study were given ample access to classroom technology and training in how to implement and use the adaptive programs. Additionally, pilot project guidelines ensured that all participating teachers followed each program manufacturers' recommended implementation timeframes for weekly student use. In this study, the teachers reflected on recent experiences that allowed for the expression of perspectives on changes in student-teacher relationships and communication, teacher role shifts, and implementation styles.

In a statewide effort to identify effective adaptive math programs, a state department of education sponsored an adaptive math pilot project with 17 school districts. The following programs were approved to be in the project:

- Accelerated Math [Renaissance]
- ALEKS [McGraw-Hill]
- DreamBox Learning [Dreambox]
- iReady Diagnostic [Curriculum Associates]
- Math 180 [Houghton-Mifflin]
- Redbird Mathematics [Redbird]
- Reflex [ExploreLearning]
- Skills Navigator [NWEA]
- Smarter Solving [Reasoning Mind]
- ST Math [Mind Research]
- Study Island [EdMentum]
- SuccessMaker Math [Pearson]
- TenMarks Math [Amazon]
- TTM [Think Through Math]
- Waggle [Waggle]

The researcher-initiated contact with superintendents and district-level administration from ten of the school districts who participated in the adaptive math pilot to identify the specific schools and CAI programs that were used by their districts during the 2016 – 2017 school year. The 10 districts were chosen based on proximity to the researcher and logistical availability. Through communication with leaders in the 10 districts, two superintendents agreed to allow the study to be conducted within their district, one district declined participation, and seven districts declined to respond to the request for participation. The agreeing superintendents each had oversight of one school that had been involved in the pilot project. These superintendents initiated contact between the researcher and building-level administrators and the researcher followed-up with these administrators to explain the scope of the study and solicit participants. All teachers within the two schools met the criteria for inclusion in the study and the building administrators communicated with the teachers directly to elicit volunteers for participation. Through this communication, seven teachers volunteered to participate in the study and the CAI programs being used were identified.

Participating schools and teachers. The study took place in seven classrooms from two public elementary schools in the Pacific Northwest of the United States. Pseudonyms have been used for teacher and school names to ensure participant anonymity. Both participating schools serve rural communities within 40 miles of a major city, and both participated in the state department of education's Adaptive Math Pilot during the 2016 – 2017 school year. Through the pilot project, the schools were provided with an orientation and training for each selected adaptive program. Classrooms were outfitted or provided access to a classroom set of computers, fulfilling a 1-to-1 student to computer ratio. For many of the participating teachers, the 2016 – 2017 school year was not their first experience having students use computers to practice math, but it was their first experience having students use adaptive programs in their classes.

Althea Elementary School. Three of the participating teachers work at Althea Elementary which has approximately 380 students and is located in a town with an approximate population of 3,500 people. Althea is a K – 5 school with a median class size of 24 students. Fifty-seven percent of the students are economically disadvantaged, 30% are Ever English Learners, and 8% of the population has disabilities. Eighty-two percent of the students are considered regular attendees, and 12% are mobile. Fifty percent of the student population is Latino, 47% is White, 2% is African American, and 2% is Multi-Racial. During the 2016 – 2017 school year, 40% of the student population met the benchmark on the Smarter Balanced Assessment Consortium state standardized math test, up from 34.7% the school year prior to data collection.

Engage New York (Eureka Math), which is aligned with the Common Core State Standards (CCSS), is used schoolwide. Teachers at Althea piloted the Reflex and DreamBox adaptive math programs during the 2016 – 2017 school year. During the year of data collection, all three participating teachers have their students use DreamBox; one teacher also has her students use Reflex, while another teacher also has her students use Zearn.

Julie. Julie teaches first-grade at Althea Elementary School who implemented the DreamBox and Reflex math programs in her kindergarten class. The year of data collection is her seventeenth-year teaching mathematics at the elementary level, and she began incorporating technology into her classroom ten years ago to review math concepts with games from online sources like ABCya and the Math Learning Center.

Katherine. Katherine is a second-grade teacher at Althea Elementary School who began using DreamBox with her class the year prior to data collection. The year of data collection is her seventeenth year as an educator, and she began incorporating technology into her elementary classroom around 12 years ago with Renaissance Reading and math review games like ABCya.

Melissa. Melissa is a second-grade teacher at Althea Elementary School who began using DreamBox and Zearn CAI math programs in her first year of teaching the year prior to data collection.

Woodward Elementary School. Four of the participating teachers work at Woodward Elementary which has approximately 430 students and is located in a town with an approximate population of 2,600 people. Woodward is a K – 5 school with a median class size of 27 students. Forty-eight percent of the student population is economically disadvantaged, 25% are Ever English Learners, and 15% of the population has disabilities. Eighty-eight percent of the students are considered regular attendees and 12% are mobile. Fifty-six percent of the student population is White, 40% is Latino, 3% is Multi-Racial, and 1% is Native American. During the 2016 – 2017 school year, 42% of the student population met the benchmark on the SBAC state standardized math test, up from 40.7% the previous school year.

The CCSS-aligned math curriculum Engage New York is used schoolwide. Teachers at Woodward piloted the TenMarks and DreamBox adaptive math programs during the 2016 – 2017 school year. During the current school year, all four participating teachers have their students use DreamBox in the math lab, during the teachers' prep times. The math lab is a computer lab where students use DreamBox for 45-minutes, once or twice per week, on a special rotation. This lab is supervised by a staff member that is not the classroom teacher, and the CAI lessons are not aligned with daily math instruction in the classroom. One teacher also uses DreamBox during her class time, and the other three teachers currently have their students use Zearn during class time.

Lynn. Lynn is a fifth-grade teacher who has been instructing at Woodward Elementary for 32 years. She began using classroom technology 10 – 12 years ago with Scantrons for Renaissance Math. Since then, her school implemented DreamBox 3-4 years ago, then stopped, at which point she began to use adaptive program MobyMax. In the school-year prior to the data collection year, she used DreamBox and TenMarks.

Tracy. Tracy is a fourth-grade teacher at Woodward Elementary. She is in her seventeenth-year teaching, began using classroom technology for non-math subjects seven years ago. The year prior to data collection was her first year using CAI for math when she piloted the TenMarks and DreamBox programs.

Amelia. Amelia teaches a blended kindergarten and first-grade class at Woodward Elementary School. Amelia is in her eleventh-year teaching, ten years at the elementary level and one year teaching middle school multiple subjects including math. She started using classroom technology on various levels from the beginning of her career, beginning with small iPods for math games and computers to use apps or online review games. She began using adaptive programs in the past two to three years. The year prior to data collection, her classroom was outfitted with to a 1-to-1 class set of iPads.

Erica. Erica teaches third-grade at Woodward Elementary School. Erica is in her fourth year teaching. Her students have been using technology in the math lab since her first year. She received six laptops the following year but did not use them for math. The year prior to data collection, her class was outfitted with the one-to-one laptops, and she started using Ten Marks and Zearn as part of her math program.

Computer-Adaptive Programs Used

DreamBox. DreamBox Learning Math is an online adaptive tool that can be used in computer labs or classrooms to provide scaffolded support aimed at closing learning gaps and moving students toward math mastery. DreamBox claims to provide a rigorous, K– 8 standards-aligned curricula with innovative digital manipulatives to allow students to demonstrate that they understand how to solve problems, not just compute answers. Rather than using multiple choice questions, it provides interactive activities meant to build conceptual understanding. Graphics and gaming features are aimed to motivate students to persist and progress at their developmental level. DreamBox Learning recommends that the program is used as a curricular supplement for 90 minutes per student, per week (Anonymous, 2016).

DreamBox claims to collect over 48,000 data points per hour and uses this information to analyze individual student responses, evaluate mistakes, and assess problem-solving strategies to provide the most appropriate next lesson. DreamBox also claims to be able to deliver educators actionable insights to monitor learning trends, differentiate instruction, and maximize student growth. They offer professional development to help schools and districts implement and utilize their program (Anonymous, 2016).

Reflex. Reflex from ExploreLearning is an adaptive, online program designed to help students develop math fact fluency. Reflex claims to efficiently move students to fluency by constantly adapting and individualizing the instruction, thus creating an optimal experience for every student. Reflex claims to differentiate instruction so that students of all ability levels have early and ongoing success. The program consistently rewards students for both their effort and progress. ExploreLearning does not recommend a set amount of Reflex time per student. However, they advise that fifteen minutes of use every day would yield faster results than forty-five minutes of use two days per week (Anonymous, 2016).

The instruction from Reflex is based on the fact family approach that uses mathematical concepts such as the commutative property and the relationships between operations. Reflex structures its lessons with instruction, practice, then assessment. Games are designed to be engaging and fun as students are led to engage in increasingly complex and quick decision making. Reflex was designed primarily for grades 2–8. Individual students can be assigned an operation set (Addition-Subtraction or Multiplication-Division) and a range (0–10 or 0–12) depending on the school's curriculum, and state standards (Anonymous, 2016).

TenMarks Math. TenMarks Math is a CCSS-aligned CAI program designed to help teachers reinforce instruction with rigorous assignments that provide videos and hints to support students as needed. The program identifies learning gaps and provides targeted instructional interventions to address the gaps. While using TenMarks, students engage in self-paced learning with personal assignments and can enter a *Jam Session* area to practice core skills. Students earn points by attempting and completing work and can redeem those points during game time (Anonymous, 2016).

TenMarks assessments are modeled on the standardized Smarter Balance Assessment Consortium and Partnership for Assessment of Readiness for College and Careers tests. The company claims that their assessments are easy to understand and the problems provide appropriate grade-level depth, rigor, and variety. Data reporting highlights concepts the class has mastered and how individual students are performing. Automated differentiation recommendations are provided to help teachers meet the needs of each student. Reports also give administrators insights into how individual students, classes, and the entire school are performing (Anonymous, 2016).

Teachers can see the learning trajectories by viewing the learning objective for each standard to see how it connects to other standards, across grade levels. Whole-class warm-up lessons are provided, and common misconceptions are highlighted so teachers can be prepared before introducing a standard. Scaffolded lesson plans with visuals can be projected in class to guide class discussions and discovery. The instructional resources can also be customized to a district’s scope and sequence. Implementation of TenMarks involves live instruction and investigation, small group and peer-to-peer collaboration, virtual instruction and practice, independent practice, at-home instructional activities, and personalized homework (Anonymous, 2016).

Zearn. Zearn is the only program in this study that was not a part of the Adaptive Math Pilot. However, Zearn is widely used at the two participating schools. Zearn is a K – 5 online instructional program designed to match the Engage New York math curriculum. Zearn provides the capacity for students to engage in independent digital lessons and matching paper lessons at their own pace. The CAI component of Zearn provides a personalized intervention pathway if a student struggles with a concept during a digital lesson. During a digital lesson, students can take structured notes while watching a video; then they can engage in guided and independent practice. Throughout the digital lesson, students receive feedback and additional opportunities to correct their work.

Zearn recommends that each lesson begins with fifteen minutes of whole-class fluency and word problems, followed by a rotation model where students work independently online for thirty minutes and work with the teacher in a small group for thirty minutes. Teachers are provided with materials to lead lessons with concrete manipulatives, direct feedback, and discussions. Activities also include whole-class warm-ups, fluency practice and word problems for each unit. Lesson and unit assessments are included in both digital and paper formats to enable teachers to understand student levels of productivity and struggle (Zearn, 2017).

Design and Procedure

After identification of potential schools from which to select the sample, teachers were contacted, and interviews were scheduled with participants. Over the course of the first semester of the 2017-2018 school year, the researcher visited the schools of participating teachers and conduct semi-structured interviews. The interviews were recorded and transcribed afterward. Participant interviews took place during the first semester of the school year and required teachers to reflect upon prior years' experiences with and without CAI and related them to current classroom experiences. Data collection was followed by inductive qualitative analysis to identify and explain themes within the responses.

Interview protocol. All interviews were scheduled in advance through building administrators; five interviews took place in teachers' classrooms, one in an administrative office, and one via telephone. Each interview was cordial and conversational, lasting from 20 – 60 minutes, and guided by predetermined interview questions. Following a brief introduction to the study and the researcher, the following scripted introduction and series of questions were used:

> Thank you for taking the time to be here today. The purpose of this interview is to better understand your perspective as a teacher who has used computer-adaptive math instruction in some way. Please speak candidly and ask me any questions as we proceed. If you want to go back and add to your previous answers, that is no problem. I'll be audio-recording this interview so it can be transcribed for further analysis.
>
> 1. Do you recall how many students you had in your class last year? Is it the number this year?
>
> 2. How long have you taught mathematics and when did you begin using classroom technology? In what ways?

3. Can you describe a typical math period in your classroom and how students receive instruction?

4. Do you currently use (program name)? What percentage of math time would you say students use (program name) and for what specific purpose?

5. How have students reacted to the introduction of (program name)? Do they appear to prefer it over other types of instruction?

6. Has the use of (program name) changed how you teach? How?

7. Has the feedback you provide changed since the introduction of (program name)? If so, how?

8. Has your control of what students learn changed with (program name)? How do you feel about that?

9. Has the integration of (program name) changed how you interact and communicate with students around academic and non-academic topics? How?

10. What are your feelings on the impact of (program name) on your relationships with students?

11. Has your perception of your role as a math teacher changed? Do you think your students' perception of your role as their math instructor has changed? If so, how?

12. Has the use of (program name) changed how you provide support to students?

13. What training and preparation did you receive prior to implementation? What are your thoughts on your preparedness to integrate (program name) into the curriculum?

14. Would you suggest any modifications to how you use (program name) or a teacher's approach with students using (program name)?

Observation protocol. An observation protocol was designed to capture the essence of the classroom environment, including teacher role and student-teacher interactions. The researcher created an observation tool stemming from two published and available observation tools. Teacher-student interactions were based on variables found in the Teacher-Pupil Observation Tool (Martin, Daley, Hutchings, Jones, Eames, & Whitaker, 2010). Classroom environment variables were informed by a classroom observation form made available by Auburn University (Auburn.edu, 2016). Drafts of the observation tool were refined through expert review and consultation with one elementary and one secondary administrator who routinely conduct classroom observations. These reviewers were provided with background information, the purpose of the study and the research questions to assist in their review. In addition to expert review, the observation tool was cross-referenced with variables of student-teacher relationships and teacher role that were uncovered in related literature discussed in Chapter Two. These variables include immediacy, proximity, communication, and leadership.

Observations were conducted in five of the classrooms that implemented a CAI program. Two of the participating teachers were not available to be observed when the researcher was available to conduct observations. Observations were scheduled to occur during the mathematics portion of each classroom's daily schedule and were conducted by the researcher as a non-participant observer. The observer entered each classroom near a transition time to mathematics instruction, the observer was introduced to the class, and the daily classroom routine resumed. The observer had minimal interactions with the teacher and students and took chronological field notes throughout each observation.

The observation protocol (Figure 2) was used as a baseline for collecting field notes. Observances that matched the categories in the protocol were noted throughout the observations. Observances that were not specifically or immediately related to a category in the protocol were also recorded to be coded and categorized later. As the researcher observed the classrooms, the researcher circulated throughout the classroom to capture the multitude of activities, communications and occurrences that were ongoing. These were captured through a combination of notes on the observation protocol, coupled with additional field notes and classroom diagrams.

Figure 2. Observation Protocol

Date: ______ Time: _______ Location: ____________________ # Students: _______ # Staff _______

Category	Description	Notes
Hardware & Programs Used		
Classroom arrangement	Desks	
	Group structure	
Instruction	Whole class	
	Small group	
	Pairs	
	Individualized	
Student activity	Computer-adaptive	
	Other computer	
	Deskwork, non-computer	
	Small group or Pairs	
	Whole class	
Teacher acknowledgment	Beginning or End of class	
	Nod	
	Action to ensure child is noticed	
	Comment	
	Feedback	
Teacher proximity	Close	
	Distant	
Student engagement	Engaged in the task	
	Not engaged in the task	
Teacher positive	Smile	
	Encouragement	
	Body language	
	Jokes	
Teacher negative	Negatively phrased comment	
	Criticism	
	Body language	
	Jokes	
Teacher leadership	Organizes & leads	
	Gives orders/sets tasks	
	Redirection	
	Management	
Student positive response to teacher	Smiling	
	Desired activity continued or initiated	
Student negative response to teacher	Frown	
	Non-compliance	
	Ignoring teacher	
	Aggression toward teacher	
Student comments	Comfort asking questions	
	Reluctant asking questions	
	Interruptions	
	Student-initiated conversation with teacher	
	Positive comments	
	Negative comments	

Figure 2. Observation protocol used as a guide for observation field notes.

Data analysis. Qualitative interview data were collected, coded, and analyzed. Saldana (2013) described first and second cycle coding that helps to identify themes and reach conclusions. The researcher-initiated a first cycle of coding on the interview transcripts in which descriptive coding was used. Descriptive coding of key topics was followed by emotion and values coding to help identify a clear picture of the beliefs and experiences of the participating teachers. Second cycle coding involved pattern coding in which the first cycle codes were assigned explanatory or inferential codes to further refine the details of each interview (Miles, Huberman, & Saldana, 2014).

First cycle codes were compiled, combined and refined through second cycle coding, related to the research questions. These codes were organized to compare responses among participants. Observation data from each participant was aligned to one of the fifty-four codes and used to verify interview responses. Logistical and contextual data was extracted from observation field notes and used to describe the coded and sorted teacher responses further. After the interview transcripts were adequately coded, cross-referenced, and supplemented with observation data, categorical aggregation, direct interpretation, and naturalistic generalizations were used (Stake, 1995).

Observation data were used to verify or expand upon the information that teachers provided in their interviews. Categorical aggregation was employed as the researcher sought patterns within the data that reveal relevant meanings arou nd teacher role, student-teacher relationships and CAI. Where individual teacher experiences differ from the rest of the sample, direct interpretation of those individual responses was conducted. Pattern coding of correspondence and frequency were used to identify and narrow themes. Throughout the analysis, memoing (Cutcliffe, 2003) was used to theorize ideas and relationships among pieces of data. Memoing allowed the researcher to develop and modify models from which to interpret the data from different perspectives, feeding back into the coding and analysis process. Patterns of responses and themes that emerged from the data are summarized, and naturalistic generalizations are made to help the education community learn from the experiences of the participating teachers.

Ethical Considerations

The Institutional Review Board granted permission to conduct this research study in the fall of 2017. All participating teachers signed consent forms to be interviewed and were given the right to review their interview transcripts, suggest clarifying commentary, or choose not to have their data included in the analysis. When published, pseudonyms were used in place of the names of participants and schools to protect anonymity. None of the participants was under direct supervision of the researcher, and the researcher will in no way serve as an evaluator for the employment of participating teachers. All data that were collected throughout this study was kept on a password protected personal computer and password protected email.

Role of the Researcher

Foremost, the researcher is an educator who has experience teaching middle school mathematics in classrooms where CAI has been utilized to varying degrees. It has been the experience of the researcher that some students enjoy using CAI, and other forms of blended learning and some students reject instruction or feedback that does not originate from the teacher. The quality of student-teacher relationships has fluctuated as the researcher has cautiously attempted to initiate some degree of CAI over the past several school years. It is imperative that I, as the researcher, do not allow my attitude toward CAI to influence the collection or interpretation of data.

In addition to being an educator, I am also a parent of two elementary school students who use CAI for some of their mathematics instruction, including homework. I see first-hand how these programs can attract and repel a child from engaging in mathematics. I also see how these programs attract my children to the computer, increasing screen-time and providing individual instruction. I kept my opinions as a parent out of this study, to not allow the experiences of my children with CAI to affect my collection or interpretation of data.

The role of the researcher in this study was to ask interview questions and conduct classroom observations aimed at unveiling the nuances of the factors that comprise student-teacher relationships in the presence of CAI. Interview transcripts were recorded and transcribed verbatim. Observation field notes, framed with the observation protocol, were used to confirm the or supplement the interview data. The innate bias of the researcher was continually kept in check throughout coding and analyses through journaling and reflection.

Trustworthiness

Assurance of credibility is established through several means. Interview data were triangulated with observation data with five of the seven participants to ensure accuracy. Data were gathered and triangulated among a wide range of participants from two different schools; while all being elementary teachers, they ranged in experience from 2 to 32 years. Individual viewpoints and experiences were compared among the participants, also adding to the dependability of the study. Member checks were performed with the participants to ensure the perceptions they relayed during their interviews were accurately represented. Two rounds of member checks occurred, participants were provided with verbatim transcripts to analyze, add to, or clarify, then participants received their interview and observation interpretation summaries to further validate the accuracy of the presentation of their perspectives and experiences.

Throughout the data collection and analysis, the researcher practiced reflexivity by making the role of the researcher clear and journaling throughout the process. Journaling consisted of hand-written notes and voice recorded memos and began as the researcher reflected on personal positionality in the research, noting potential bias from past experiences using CAI. During the interview process, the researcher was mindful of personal biases and restrained from making comments to the participants that may imply particular feelings for or against CAI use. As themes were generated during data analysis, journaling was used to note the researcher's feelings on the themes and how they compare to prior personal assumptions or biases. This journaling, in conjunction with the established role of the researcher and noted personal biases, also add to the confirmability of the study.

Transferability has been established by selecting participants from two separate schools and with a wide range of backgrounds in education and with technology integration. Interviews yield thick descriptions of the perceptions and experiences of the participating teacher, from which further research can relate to and build upon.

Summary

This study is time-bound by the 2017-2018 academic school years and includes seven elementary teachers that used CAI during the 2016 - 2017 school year. Semi-structured interviews took place in the first semester of the school year and required teachers to reflect upon prior years' experiences with and/or without CAI and relate those experiences to their current situation. Focusing on the perspectives of elementary mathematics teachers implementing CAI shed light on changes in student-teacher relationships, teacher role shifts, and implementation styles. Interviews were transcribed, coded, and qualitatively analyzed in the first and second semester of the school year. Individual teacher responses and collective themes are summarized, and naturalistic generalizations are made to help the education community be more informed about the effects of implementing CAI programs. Through the application of ANT, a model emerged that relates prime considerations of teacher role and student-teacher relationships to the connections between students, teachers, and programs within the computer-adaptive learning environment.

Chapter Four: Results

This chapter presents the findings from an inductive qualitative study that explored teacher role and student-teacher relationships through the implementation of CAI math programs at two elementary schools in the Pacific Northwest of the United States. A qualitative research design with inductive analysis was used because this study sought to obtain teachers' perspectives on experiences within their classrooms and relationships with their students. Teachers' perceptions of these newly implemented technology programs were unknown, and this research describes and examines the experiences currently taking place in classrooms. Examining teacher-student interactions and teacher roles as described by the teacher, uncovered the meanings constructed by teachers throughout the phenomena of CAI program implementation. As constructed meanings are expressed through language, both implicitly and explicitly, interpretivism was used to bring understanding the complexities of meaning around teachers' perceptions.

The experiences and views expressed by the participants in this study were condensed into themes, and further attempts were made to highlight both common and unique perspectives of teachers to encompass the full scope of their experiences when adopting CAI programs. To that end, interview data were collected and analyzed in hopes of gaining new perspectives on the implementation of CAI programs and how they can best be used or not used while supporting positive student-teacher relationships. Teacher interviews were followed up with classroom observations to obtain contextual *teacher negative* information, confirm, or supplement the teachers' perceptions.

Throughout each observation, it became clear that the protocol form would not be completed entirely as the observer made notes that were necessary to capture the essence of the math classroom experience. The section was not completed for any of the observations because there were no interactions between students and teachers to fit the category. Observation data were used to confirm and supplement participant interview data.

Data synthesized from participant interviews and observations are presented as they relate to one or more themes. Unique accounts of each teacher speak in details that generalized themes cannot always capture. Therefore interview narratives, observation data, and researcher interpretations are included in to help illuminate the experience and perspective of each teacher. Interview data were collected from seven teachers in two elementary schools. Observations were conducted for confirmatory analysis of the interview data for five of the participants. First-round descriptive and values coding were followed by pattern coding in which correlation between and frequency among codes were used to identify and narrow categories. This was accomplished through the creation of a matrix in which participants were aligned along a horizontal axis and their codes were listed and explained along a vertical axis. Through this matrix, commonly occurring and similar codes were identified and further refined. Categorical aggregation was performed and led to the determination of prominent and supporting themes related to teacher role and student-teacher relationships.

Findings are organized by primary relation to one of two research questions; it should be noted that the inextricable connection between teacher role and student-teacher relationships can lend a particular finding to address both questions. Five themes emerged to describe teacher role: Teachers as personal instructors, individualized instruction, teacher trust in and deference to programs, role shift from learning facilitator to program assigner, and teacher as classroom and instructional leader. Three main themes emerged to describe student-teacher relationships while using commuter-adaptive programs: Teacher proximity, communication, and support. The following research questions were investigated:

1. How is teacher role impacted through the implementation of computer-adaptive instruction programs?
2. How do teachers perceive their student-teacher relationships through the implementation of computer-adaptive instruction programs?

Data Sources

The findings presented in this chapter draw from teacher interviews and classroom observations. Teachers from each grade level, kindergarten through fifth grade, were participants in the study. All teachers were observed except one fifth-grade and one kindergarten-first-grade blended teacher. Three teachers work at Althea Elementary School where the DreamBox, Zearn, and Reflex CAI math programs were implemented in the classrooms. Interviews and observations were conducted with all three teachers. Four teachers work at Woodward Elementary School where DreamBox, TenMarks, Zearn, and MobyMax CAI programs have been implemented. Interviews were conducted with all four teachers and observations were conducted for two of them.

Teacher Experiences

The following section provides interview narratives, observation data and interpretations of the experiences the teachers have lived while implementing CAI programs. These personal accounts, synthesized with observation data, are intentionally kept intact by teacher to provide holistic views of the unique situations within each classroom. These holistic views allow the reader to identify with or contrast particular classroom experiences and give context to each teacher's account, allowing finite details to be seen. The story of each teacher reveals subtle to strong differences in teachers' experiences of CAI program implementation, many of which are linked to the themes of this research. The accounts and interpretations of each participant's experience are valuable in providing a wider view of the current state in computer-adaptive classrooms; a wider view that can illuminate nuances among experiences and entry points for further inquiry.

Julie. With seventeen years teaching experience, Althea Elementary first-grade teacher, Julie uses a combination of the Reflex and DreamBox programs to provide concept review and math fact fluency practice. Her students spend an average of 15 minutes per day using an adaptive program. Since the introduction of the programs, Julie has modified which mathematical models and practice sets she uses in response to the mathematical representations that are presented in the program. She will reduce her coverage of particular strategies and models and put trust in an adaptive-program to do so if she feels the program provides adequate opportunities for practice and support in that area. She also appreciates that the programs align with the CCSS, but needs to make modifications to the lessons she teaches because the programs do not cover all the required standards for her grade level. Her role as a teacher in relation to her students is otherwise unchanged by the introduction of the CAI programs.

Julie feels that using adaptive programs does not significantly impact her relationships with her students. The programs do, however, allow her to use a station rotation model where she interacts with students in small groups. It is important that her students be able to work independently while using the adaptive-programs to allow her to engage in more personalized interactions with the other students in the class. Julie does not use the data from the programs to provide feedback to students beyond seeing if the students are progressing or staying on the same topic for extended lengths of time.

Julie wishes that the CAI math program covered all the subjects because it is aligned with CCSS and also helps them with their standardized testing. The technology skills that are required to answer the questions on the DreamBox are often similar to what they have to do on standardized math tests. Julie suggests the programs provide more information to teachers on what specific computer skills students use in the program that students also use on standardized tests.

Observation. A classroom observation was conducted at 8:55 a.m. with one observer, Julie, and 16 students present. Julie led a whole-class activity where students were engaged, active, and running in place while watching *Go Noodle,* projected on the board. They moved into a hip-hop themed dance activity while watching and explaining money related mathematical problems. Julie then led a whole-class Eureka math Google presentation on the daily objective, subtracting 7, 8, and nine from teen numbers.

Students watched and volunteered answers as a student wrote on the whiteboard while the teacher assisted in solving sample problems.

At 9:15 a.m., students dispersed to table groups with an average of 3 students per group. Julie led a math sprint, fluency speed drill, then students listed how many problems they completed. At 9:22 a.m., students regrouped on the classroom carpet while Julie led whole-class direct instruction to provide concept development on the daily objective. At 9:30 a.m., the class transitioned into a station rotation model.

Students were directed to one of three centers: Polygon hand-held manipulative free play, Reflex CAI program, or teacher-led small group instruction and assistance. Students spent an average of 10 minutes at each center.

Students at the polygon center moved freely in a carpeted area and built objects by connecting numerous assorted polygon tiles. The students at this center worked independently and cooperatively, and the exploratory construction free play did not require any attention from the teacher.

Students that moved through the Reflex center experience varied levels of success engaging with the program. The students who were able to access the program worked through a cartoon-based carnival scene where they matched numbers worked on addition fluency. The students completed the math tasks without whiteboards or paper and pencil for processing. Students had only used this particular program in class for a week, and some students had difficulty remembering how to log in to the program. Other students had caps locked on their keyboards and were unable to log in without assistance. Julie needed to split her time between her small-group center and the Reflex center because the students were not able to use the program independently.

As students who rotated through her teacher-led small-group center, they worked on a paper and pencil problem set consistent with the daily learning objective. When Julie was working with her small group, she provided instruction and assisted individual students in understanding how to solve the problems. For approximately half of her small-group time, Julie needed to leave her small-group center and assist the students at the Reflex center. This gave less time for her to interact with the students at her center, as students sat or worked independently on the problems while she worked with the other students who were struggling with the CAI program.

The center rotations lasted for 30 minutes, the length of three cycles and the observed patterns were consistent through all of the rotations. At the conclusion of the center rotations, students transitioned out of math time at 10:00 a.m. by cleaning up the polygon center and taking laptops to a storage cart outside of the room.

Interpretation. The classroom observation confirmed the themes that Julie described in her interview; themes including the belief in whole-class direct instruction led by a strong teacher and the ability for students to work independently while using the CAI program to facilitate a station rotation model.

Students in this class spend 10 to 20 minutes per 60 to 75-minute math period using a CAI program. The programs are used to provide students concept review and math fact fluency practice, in addition to providing the teacher with a purposeful activity that will occupy the students, clearing the way for her to have personalized interactions with students who are not using the programs.

Julie does not feel that using adaptive programs significantly impact her relationships with her students beyond allowing her to interact with smaller groups at certain times. Observation data confirmed that it is important that her students be able to work independently while using the adaptive-programs or she cannot engage in more personalized interactions with the other students in the class.

During the observation, Julie interacted with her students directly and patiently to encourage on-task participation and assist learning. She kept close proximity to her students as she led the whole-class portions of her math lesson. Julie continued to work in close proximity with one-third of the class at a time, while the students rotated through centers. She engaged with the students who were working on the computers, only to ensure that they were able to log in and proceed with the program.

Katherine. Katherine is a second-grade teacher at Althea Elementary School who began using DreamBox with her class the year prior to data collection. The year of data collection is her seventeenth year as an educator, and she began incorporating technology into her elementary classroom around 12 years ago. Katherine's students use an adaptive-program for approximately 30 minutes per day.

Katherine uses a CAI program to provide personalized math instruction for intervention and extension purposes. The program provides her students with additional opportunities to learn in a non-collaborative way. She trusts that the program will reinforce the skills that she has taught. Katherine believes that a teacher needs to be a strong leader that can provide effective direct instruction and foster student discourse around mathematics. She believes that people learn best when they interact with one another and collaborate. Katherine does not feel that using the adaptive program has changed how she leads direct instruction or how she fosters collaboration and communication in her classroom.

Katherine feels that using an adaptive program may make her students like her more because modern-day students are immersed in technology and enjoy spending time using on computers. She is conscious of the amount of screen-time exposure that students receive and she limits screen-time in her classroom to non-gaming, purposeful use. Katherine wants her students to understand that she believes this particular form of technology use will benefit them academically and she is careful to communicate with her students that the time they spend on the computer is for the purpose of learning. Katherine likes that the program gives students instant feedback and she acknowledges that the program provides independent time for students to work without the need for her to interact with them.

Observation. A classroom observation was conducted at 1:12 p.m. with one observer, Katherine, and 22 students present. The classroom layout included six student tables where students sat in small groups. Katherine introduced the observer to the class as students sat in their seats, she dismissed the students from their seats and they quietly, and orderly transitioned to the carpet.   The math lesson began with the students sitting closely together on the carpet and Katherine directing whole-class calendar and weather time with a student leader. Students continued to engage in mathematical talk about shapes and fractions amongst themselves and with the teacher for approximately 20 minutes, then transitioned into completing a paper packet involving names for multi-digit numbers until it was completed. Around 2:00 p.m., students were directed to check their work with a peer when they finished, then use DreamBox or work from *Digging into Math*.

Students transitioned to the CAI program independently upon completion of their work packets. Katherine worked with a group of students who needed more support completing the packets while the other students logged in to DreamBox, put on headphones, and began working. Students using the CAI program were observed working through a variety of cartoon-style activities targeting addition and subtraction, and place value. Katherine continued to provide individualized instruction on the daily concept in the packet, with a small group of students. One computer needed to be restarted, requiring a brief response from Katherine, otherwise, the students using DreamBox functioned independent of teacher attention until the end of the math period around 2:30 p.m. By that time, three students had chosen not to use the program and instead worked together on paper-based *Digging into Math* problems. All the while, Katherine continued to work with the small group of students who still needed individualized attention to understand the concept of that day.

Throughout the observation, the class functioned at a low volume and flowed orderly. Katherine interacted with her students calmly and personally to ensure proper behavior and engagement. Students responded positively to her when she spoke with them. She sat in front of her students and kept close proximity to them while leading whole-class instruction and discussions. Katherine continued to work in close proximity to the students who needed extra support and intervention. She did not engage with the students who were working at the computers, beyond giving reminders for the purpose of the computer work, behavior prompts, or tips for computer troubleshooting.

Interpretation. The classroom observation confirmed the themes that Katherine described in her interview; themes including a value in interpersonal interaction for learning, the need for a strong educational leader to direct and instruct, and the ability for students to work independently while using the CAI program. A beneficial byproduct of the CAI program use is the automated attention grasp that it can have on students, allowing for the students to be independently occupied by the program. It appears that the relationship between Katherine and her students is established from contexts beyond the CAI program and the program serves as additional review and concept extension.

There is not an equal distribution of CAI program use among the students. Some students spent up to 30 minutes using a CAI program during this 75-minute math period. Some students in the class receive far fewer minutes using the adaptive program because of their work completion speed, concept comprehension level and need for teacher-student intervention time.

The CAI program is used to personalize math instruction by providing interventions and extensions with which students can engage independent of each other or the teacher. Katherine puts her trust in the program to provide instant feedback and reinforce skills that she has taught, but she double checks areas where she has found the program does not address grade level standards. She believes that people learn best from each other and wants to be sure screen time that detracts from interpersonal interactions is high quality and not wasted screen time. It does not appear that using the adaptive program has changed how she leads direct instruction or how she fosters communication in her classroom, but it has allowed her to work with students individually while the other students are using the program.

Katherine believes that modern-day students enjoy using computers and students appreciate when they can use the devices in class. There are times when accessing the CAI program becomes a distraction for her students. The movement required for selected students to obtain computers from outside of the room and set them up in the room distracts those students who are not using the computers. Distractions also arise around technology hardware and software issues that require additional teacher attention or attention from other students in the class. These issues risk a loss of limited and critical learning time, as students may not be on task or Katherine may need to divert her attention away from working with individual students to addressing technical difficulties.

Melissa. Melissa is a second-grade teacher at Althea Elementary School who began using DreamBox and Zearn CAI math programs in her first year of teaching the year prior to data collection. Melissa has her students use one of the adaptive programs during and outside of math-class time for an average of 30 minutes per day.

Melissa uses the Zearn program to teach and review the exact same concepts that she teaches on a given day in class. Zearn has made a difference in her role as a teacher in that she ensures that the concepts, models, and terminology that she uses with her students matches those of the program. She uses DreamBox as a supplement to provide review and additional practice on other mathematical skills. To that end, Melissa does not feel that DreamBox has affected her teaching in any way. Melissa wants to be able to let go of her direction of some student learning and allow the students to direct some of their own. She acknowledges that sometimes the programs will start to direct student learning in ways that she had not considered. As long as she is aware of what her students are doing on the programs, she is comfortable putting her trust into the program to cover concepts in different ways. She admits that it is really easy sometimes to let the computer take over and it is important to find a proper balance between teacher-lead and CAI program use.

The interactions that Melissa has with her students have changed with the use of the CAI programs. Melissa has half of her class use the programs independently while she works with the other half of the class. This modified rotation model has allowed Melissa to teach to a smaller group of students at any given time. Her students have begun noticing connections between the Zearn lessons and the lessons that she provides with the class, allowing for enhanced academic communication. Melissa does not feel that student use of the CAI programs has negatively affected her ability to communicate with her students, rather the programs are a positive reinforcement of what she covers in the classroom.

Observation. A classroom observation was conducted at 1:30 p.m. with one observer, Melissa, and 21 students. The classroom layout included five tables where students sit in small groups and area with a U-shaped table near the white-board for larger group instruction. At the beginning of the observation, the class engaged in whole-class learning around breaking hundreds into groups of ten. Melissa was working through the concepts on the whiteboard as her students responded and drew representations on their personal whiteboards.

Students continued to engage in the whole-class lesson until 1:38 p.m. when Melissa split the class into two groups. One group was dismissed to get a computer and begin using Zearn, and the other group was to stay with Melissa for more instruction and concept development. Many students produced audible excitement for the transition to Zearn while a few expressed discontent.

Students working with Zearn took their computers from the charging cart, sat alone or in groups up to three, put on their headphones and began to use the program. Melissa began a warm-up with her group, then left them briefly on a few occasions to ensure that students were correctly logged in to Zearn. Three students needed assistance logging into the program. Melissa worked with half of the class at the whiteboard modeling concepts of place value with monetary examples. Students followed along and worked out representations on their personal whiteboards. Throughout this time, Melissa interacted with students directly and personally to manage student behavior, as the classroom was lively with student talk.

Most students were using Zearn to complete computer-based activities that replicated what Melissa was teaching to the other half of the class. Three students using the program were not engaging in activities related to the daily lesson, those students were reviewing previously taught concepts such as simple subtraction. Students on the program wore headphones and worked autonomously, at times talking to one another.

These observations were consistent until the end of math time at 2:05 p.m. On a typical day, the math time would continue similarly for 30 more minutes, a student rotation between computers and teacher-led activities.

Throughout the observation, Melissa kept close proximity to half of her class, instructing those students on the daily math concept. Students responded positively to her when she gave instruction and feedback. She did not engage with the students who were working at the computers, beyond initial circulations amongst the computer users to ensure login success.

Interpretation. The classroom observation confirmed the themes that Melissa described in her interview; themes including an integration of technology to support specific daily learning objectives, trust in the CAI program to administer appropriate educational content, and the ability for students to work independently while using the CAI program. A byproduct of using the CAI programs that benefits the non-users is the allowance for the teacher to interact with a smaller group of students while other students are independently occupied by the program. It appears that the relationship between Melissa and her students is established to include the CAI program and the program serves as an additional review, instruction, and concept reinforcement.

Melissa wants to be able to let go of her direction of some of the student learning and allow the students to direct some of their own and she acknowledges that the programs will start to direct student learning in ways that she had not considered. She is comfortable putting her trust into the program to cover concepts in different ways, as long as she is aware of the methods the programs use. She admits that it is easy to let the computer take over and it is important to find a proper balance between computer and non-computer time.

Interactions between Melissa and her students are affected by the use of Zearn as students make connections between the online and in-person activities. She has more distant contact and minimal interactions with the students using either of the programs. Melissa believes the CAI programs are a positive reinforcement of what she covers in the classroom.

Lynn. Lynn is a fifth-grade teacher who has been instructing at Woodward Elementary for 32 years. She began using classroom technology 10 - 12 years ago with Scantrons for Renaissance Math. Since then, her whole school implemented DreamBox 3-4 years ago then stopped, at which point she began to use adaptive program MobyMax. In the school year, prior to data collection, she used DreamBox and TenMarks. This year, her students use DreamBox in the math lab twice a week for approximately 45 minutes during each session. In class, her students use Zearn and a lite version of MobyMax three days per week, for 20 – 25 minutes during each 80 or 85-minute math period.

Lynn uses her current CAI programs to provide review and additional practice and does not rely on the programs for rigor or mathematical discourse. She monitors and interacts with her students as they work on the programs and does not leave them to work independently while she works with other groups in the class. She notices that her students have less perseverance when using the CAI programs this year, a stark contrast to the engagement with TenMarks the year prior to data collection. Lynn believes that students learn best from one another; when they engage in conversations with other students and the teacher. Lynn does not feel she has used adaptive programs in ways that change her role as an instructor or how she fosters collaboration in her classroom.

The year prior to data collection, the TenMarks program provided her students with rigorous tasks that necessitated student-teacher communication and teacher support. Her experience with TenMarks provided opportunities for social and off-computer learning between herself and the students, impacting their relationships around mathematical contexts. The CAI programs Lynn currently uses do not provide the level of rigor that she feels is necessary to foster meaningful engagement or teacher-student communication. Lynn does not think the information she gleans from the current CAI programs is actionable for her to provide helpful mathematical feedback to her students or engage in discussions with them about that work. Lynn rationalized that if she depended on the technology too much, she would not be able to relate with her students mathematically. According to Lynn, if CAI programs are going to be used more extensively, they need further development to allow interpersonal communication through the program. Communication is a critical component to learning, and the current iterations of the CAI programs she has used have not fostered meaningful mathematical communication.

Lynn suggests the programs have a component where the students can have a discussion within the technology if schools try to use the programs exclusively. The program needs a place where the students can have chats not just with the computer programmer at the other end, but where they can have that conversation with each other. She stresses that conversation is so important in understanding math.

Tracy. Tracy is a fourth-grade teacher at Woodward Elementary. She is in her seventeenth-year teaching, began using classroom technology for non-math subjects seven years ago and has progressed from using iPods to Chromebooks. The year prior to data collection was her first year using CAI for math when she piloted the TenMarks and DreamBox programs. During the year of data collection, her students use Zearn for approximately 35 minutes during a typical 75-minute math period and use DreamBox for approximately 45 minutes twice a week while in the math lab.

Tracy uses a CAI program to provide additional opportunities for her students to interact with math content. The program is primarily used for review, and additional practice, and Tracy believes her students have learned more because they have more opportunities. She says using the program has definitely changed her role as a teacher, as she can provide more individualized instruction than she could in the past. She believes that modern-day students have a different perspective than students in the past because they are so much more technology oriented. Therefore the adaptive program suits them nicely. Tracy believes her students are more motivated when using technology than without it.

Tracy feels that using adaptive programs do not significantly impact her relationships with her students. The programs do, however, allow her to use a station rotation model where she interacts with students in small groups. It is important that Tracy's students be able to work independently while using the adaptive-programs and other centers within the rotation to allow her to engage in more personalized interactions with the other students in the class.

Observation summary. A classroom observation was conducted at 12:03 p.m. with one observer, Tracy, and 28 students. The classroom layout included a whiteboard, six desk-groups and a U-shaped table near her desk used for small group instruction. Class started as students entered the room from recess and walked directly to one of five centers. Her students rotated through the five centers at 11-minute intervals, until the conclusion of the math period.

At one of the centers, Tracy worked with groups of four to six students on the daily math objective. Tracy and the students were working through sample problems involving the area model for division on individual whiteboards. Tracy interacted calmly and quietly to help explain the concepts to her students and provide them with personalized feedback. She would occasionally speak up from her group to remind students to stay on task at the other centers and students responded positively. Beyond these reminders from Tracy, the other four centers operated independently and without interaction from the teacher.

Students used the Zearn program at two of the centers, totaling 22 minutes of CAI use. Student laptops had whiteboards affixed to the back of the screens for students to use as needed for processing concepts and solving problems. Most students wore headphones and had limited interaction with the other students with using the program. The program provided a video tutorial on the daily concept, word problems, and a fluency drill. Students had freedom within the program to choose their activity, thus experienced a wide range of mathematical problems and challenge levels. Concepts that the student were seen covering included area, perimeter, multiplication, subtraction, place value, rounding, and inequality statements.

One center involved fact fluency practice where students completed multiplication problems on worksheets. There was very little communication between the students at this center, and they worked independent of interaction with the teacher.

At another center, students worked on a problem set from their worksheet packet of the Engage New York curriculum. These problems were related to the daily objective of representing division with area models. There was limited student-student communication at this center as students worked on making sense of the problem set. Some students worked diligently and independently on their task, others were slow to begin working, and some asked each other for assistance in understanding what to do.

Throughout this time, Tracy engaged with students kindly and personally to manage student behavior, and help students follow expectations. These observations were consistent until the end of math time at 1:00 p.m., when students were instructed to clean up their center and return to their desks. Throughout the math time, Tracy kept close proximity to a small group of students, instructing them on the daily math concept. The remainder of the students in the class worked virtually independently as they rotated through the centers. Students responded positively to her when she gave instructions and feedback, and she otherwise did not engage with the students who were working at other centers.

Interpretation. The classroom observation confirmed the themes that Melissa described in her interview; themes include an integration of technology to support specific daily learning objectives, trust in the CAI program to administer appropriate educational content, and the ability for students to work independently while using the CAI program. It appears that the relationships between Tracy and her students are established external to the CAI program, and the program allows her to interact with those students who are not using the program.

Tracy uses Zearn to provide extra opportunities for her students to interact with math. The program is primarily used for review and additional practice, and she believes her students have learned more because of it. The program has changed her role as a teacher by providing more individualized instruction than in the past. She feels her students have a different perspective than past students because of their orientation and affinity for technology. Therefore the adaptive program suits them well. Tracy believes her students are more motivated when using technology than without it. The classroom observation was not able to confirm a student level of motivation or perseverance when using the program, as students were able to freely click into and out of activities of their choice representing concepts from a range of grade levels.

Tracy does not feel that using adaptive programs significantly impact her relationships with her students, but they allow her to use a station rotation model where she interacts with students in small groups. It is important that students be able to work independently while using the adaptive-programs and other centers to allow her to engage in more personalized interactions with other students.

Amelia. Amelia teaches a blended kindergarten and first-grade class at Woodward Elementary School. Amelia is in her eleventh-year teaching, ten years at the elementary level and one year teaching middle school multiple subjects including math. She started using classroom technology on various levels from the beginning of her career, beginning with small iPods for math games and computers to use apps or online review games. She began using adaptive programs in the past two to three years. The year prior to data collection, her classroom was outfitted with to a 1-to-1 class set of iPads. Students spend 15 minutes of their math class on the DreamBox program, and 30 minutes on the program at the end of each regularly scheduled day. Some students choose to use the program for an additional 10 minutes at the start of each day. In addition to the in-class usage of DreamBox, her students also use the program in the school math lab an average of two 45-minute sessions per week.

Amelia uses a CAI program to personalize math instruction with interventions and extensions. She appreciates how well the program aligns with the Engage New York curriculum that she uses in class. Amelia does not believe DreamBox has changed how she actually teaches, however using the CAI program has impacted her role as a teacher by providing additional support to students. Amelia believes the program has increased feedback on student comprehension and progress to her and her students, providing another way to assess their level of understanding. Program usage has also allowed her to implement a station rotation model in her classroom, where she can have more personal interactions with those students not using the program. Amelia trusts that the CAI program will provide lessons to students at their level and students can engage with appropriate content, without much additional work from her. Along those lines, she appreciates that the program will catch gaps or provide extensions in student learning that she may otherwise miss.

After the introduction of CAI programs, the relationship between Amelia and her students was bolstered by increased communication and feedback between her and her students. Beyond this increased communication and feedback, she feels that the introduction of the adaptive programs has not impacted her relationships with her students. The ability of the programs to work with students independently allows her to communicate with other students personally, to address their unique learning needs. Amelia notices decreased levels of student engagement in the program and suggests incentives from the teacher to help increase student perseverance in using the program. She wishes the program was able to do more to enhance student learning.

Amelia suggests teachers have some incentives to have their students' complete lessons. She has witnessed students click in and click out of various activities because they have that option, and there are many different things they can choose from. Actions to help students work on perseverance and complete their computer-adaptive tasks is something the students need help with.

Erica. Erica teaches third-grade at Woodward Elementary School and is in her fourth-year teaching. Her students have been using technology in the math lab since her first year. She received six laptops the following year but did not use them for math. The year prior to data collection, her class was outfitted with the one-to-one laptops, and she started using Ten Marks and Zearn as part of her math program. During the year of data collection, her students spend approximately 20 – 25 minutes per day using Zearn during a 90-minute math period. In addition to in-class use, her students use DreamBox in the school math lab an average of two 45-minute sessions per week.

Erica uses Zearn in class for her students to engage in fluency, practice, and math chats. She does not consider the program to be truly computer-adaptive. While Zearn provides remediation pathways and allows students to complete individual lessons at their own pace, it does not automatically adapt to student learning levels to the degree that other CAI programs can. Erica feels that Zearn has definitely affected how she teaches, sometimes she projects and uses the program for her whole-class instruction time, then leads the students in a scripted portion of the lesson. She appreciates that the program has given her more tools to use. The year prior to data collection, the TenMarks affected her control of student learning by allowing individual students to move several grades ahead in math concepts, independent of her instruction. Computer-adaptive program use also allows Erica to use center rotations in her classroom, where she has personal interactions with students while the others are using the program.

TenMarks, the CAI program that Erica used the year prior to data collection provided information to give students personalized feedback. Zearn does not give her actionable feedback for her to work with students and DreamBox might be able to provide that data, because students use it in the math lab during her prep, she does not take the additional time to use those extra reports. The year prior to data collection, the TenMarks program enabled her to create intervention groups based on student data from the program. The ability to work with students in those like-skilled groups affected the communication and support she could provide to her students. Because that feature is not available with the program she uses in class this year, Erica has now chosen to use a separate paper quiz to create intervention groups. Erica works with small groups of students, then circulates the room and monitors her students as they use the computer program during class time. Erica thinks it is bit scary that future students could get the learning resources and instruction normally taught by her, from a program instead.

Erica thinks that CAI programs work well with station rotations. They have helped her ensure students receive enough time at the teacher-led instructional station. Erica shares, "I definitely think if a teacher is doing rotations, making a computer-assisted center is good to do."

Erica explains the customizability of the program she used the year prior to data collection, "You could give a student the third-grade assessment. Then based on how they did with that, it would populate assignments for them on those gaps that they had. Even if it were a gap from something in kindergarten, they would do a lesson on it, and then have to prove that they understood. Then I could also put in the standard of what we were doing that day in class, and they can process that also. You could customize it."

Observation summary. A classroom observation was conducted at 1:42 p.m. with one observer, Erica, and 27 students. The classroom layout included seven student tables, a whiteboard, and nearby carpet area. At the beginning of the observation, the class was sitting on the carpet, engaged in teacher-led whole class direct instruction. Erica projected lesson prompts and problems from the Engage New York curriculum as she and a student leader worked out problems on the board. Students used individual whiteboards to create mathematical representations and process the lesson about creating and solving single-variable multiplication equations to represent real-world situations. At 2:05 p.m., students transitioned efficiently to their table groups to work on the daily problem set.

Students sat in small groups and worked independently with paper and pencil on a daily problem set consistent with the topic of the day. Students appeared to know the class routine as they moved efficiently between activities and began working in their packets. Students worked on their packets for 15 minutes as Erica called small groups of students to a table where she used sample problems to check the level of understanding for each student. Students were released from her small group back to their table groups when they were able to demonstrate that they understood the concept. Erica worked calmly and efficiently with her students as she called them up to her table. At 2:22 p.m., the whole class transitioned to computer time, where they used the Zearn program.

All of the students sat at table groups, donned headphones, and independently used Zearn. Students were all observed watching video explanations of the daily topic, and working on the same mathematical concepts involving multiplication grids, arrays, and equations. During this time, Erica kept close proximity to the students, circulated the room and monitored their computer use. Erica quietly engaged several students to provide targeted assistance with the lesson in the program. Once students completed the daily objective on Zearn, the program unlocked various choice activities that students could use for review and practice. These observations were consistent until the end of math time at 2:40 p.m.

Interpretation. The classroom observation confirmed the themes that Erica described in her interview; themes including an integration of technology to support specific daily learning objectives, and trust in the program to provide appropriate educational content. It appears that the relationships between Erica and her students are established with the CAI program in place. She monitors her students closely as they use the program in class and she uses student questions derived from the program as avenues for student interaction.

Erica has her students use Zearn in class for daily concept development, review, fluency, practice, and math chats. She does not consider Zearn to be a CAI program because it does not automatically adapt to student learning levels in the same way as other CAI programs. Using Zearn has affected how she teaches, sometimes projecting and using the program for whole-class instruction, and using a scripted portion of the lesson. Computer-adaptive program use allows Erica to use center rotations in her classroom. Although her methods of center rotations differ from her colleagues, she has personal interactions amongst the students while they are using the program.
The TenMarks program, provided information to give students personalized feedback, but Zearn does not give her actionable feedback for her to work with students. DreamBox might be able to provide that data, but she does not take the additional time to use those extra reports. TenMarks also enabled her to create intervention groups and her ability to work with students in like-skilled groups affected the communication and support she provided. Erica works with small groups of students, then circulates the room and monitors her students as they use the computer program. Erica is wary that

future students could get the learning resources and instruction from a program instead of a teacher.

RQ1: How is teacher role impacted through the implementation of computer-adaptive instruction programs?

Through the analysis of participant interviews and observations, five themes related to teacher role emerged: Teachers as personal instructors, individualized instruction, teacher trust in and deference to programs, role shift from learning facilitator to program assigner, and teacher as classroom and instructional leader. Each of these themes are discussed and related to specific teacher experiences.

Teachers are situated as personal instructors during a fraction of students' math time, in a station-rotation model. Descriptive coding and observation data revealed a station-rotation model was common and logistically compatible with CAI program implementation. Not all teachers use a rotation model but are still able to meet with students one-on-one or in small groups while the program engages with the other students. The degree of structure varied among classrooms, as some students used CAI programs more than others during flexible times at various points in the day. Varied forms of station-rotation models, with more or fewer groups and rotation intervals, allowed teachers to work with students one-on-one and in small groups to meet unique student needs. Students rotated through several learning centers at regular intervals, interacting with adaptive-programs for 20 – 60 minutes each day, spending approximately 20 – 40% of math time using CAI programs. Teacher-led small-group stations were locations for students to interact in close proximity with teachers, receiving personalized instruction and support. Teachers interacted with students in small groups for 5 – 20 minutes during a typical math session, situating each student with approximately 13 – 38% of their math time interacting with the teacher. Five of the seven teachers implement learning centers using a station rotation model, and the other two teachers plan to implement the model.

Computer-adaptive program use enhances the ability of teachers to implement learning centers by autonomously and independently occupying students at one or more centers. The teachers trust the program will engage students at a learning center so that the teacher may work with other students in a smaller group. The rotation model positions the teacher as a personal instructor for fewer students at shorter intervals, supporting the personalization of teacher-student interactions. This model has implications for the proximity of students to teachers and is a factor of student-teacher relationships.

According to Amelia, "It has allowed me to have centers and make sure that students are on task, that has been nice especially with a blend of kindergarten and first-grade. If students get on this program, it is going to be exactly where they are supposed to be without too much additional work on my part… It gives me a chance to interact with them one-on-one and in small groups while the others are working at their levels."

Melissa shares, "Even with the integration of the programs, I still try to have that smaller group that I work with while the other group of students is using the programs. It actually helps to have them on the programs because I can work with the smaller group versus working with the whole group all the time."

According to Julie, “When they are using the programs, it is a time when I am not with them, so I do not keep my thumb on them to follow the instructions.” Teachers keep close proximity to the students within their small group and remain distant to the students working on the programs.

The implementation of CAI programs as part of a station-rotation model gives teachers opportunities to interact with students one-on-one and in small groups. The proximal interactions between students and teachers in small groups allow teachers to support learning for students at various levels. Teachers may group students by ability-level so instructional interactions can meet common student needs. Teachers place trust in the programs to engage students and foster student learning while the teacher works with other students.

Individualized instruction from teachers and programs. Descriptive coding resulted in a theme of individualized instruction, over which second-cycle pattern coding identified factors relating to that individualization. This theme is similar, yet distinctly different from the theme of teachers situated as personal instructors, as this theme addresses the individualized instruction component that can be provided or informed by a CAI program. Teachers expressed the ability to provide more individualized instruction for their students as a direct result of a program (i.e., one-on-one communication with students stemming from student interaction with the program) or indirect result of the program (i.e., allowance for teacher-student small group interaction separate from the program). In addition to addressing grade-level and remedial concepts, teachers use the programs to assign students content from higher grade levels, allowing students to work at their own pace, ahead of daily class lessons.

Teachers can be situated to interact with students on a one-on-one and small-group basis when CAI programs are in use, and both teachers and CAI programs provide individualized instruction for students. Teacher-led small group instruction can be informed by student program data while CAI adjusts for student understanding.

Data generated from the program can inform personalized teacher-led instruction in small-group situations. Erica says, "As far as having these programs impacting my relationships with students, it is just the data in general that helps… I can get more targeted instruction to them based on that information." According to Amelia, "It has increased communication regarding on task or where their challenges are, and it allows students to let me know how they are feeling about it or what they are struggling with." Teacher-led personalized instruction is not the only type of individualization can be accompanied by adaptive-program-led personalized instruction.

The programs themselves, provide the instruction on topics relating to daily classroom objectives as well as extended and remedial concepts. Erica shares, "It has given me more tools to use…I had a couple of tag students so I could put them at fifth-grade concepts that matched what we were learning but at a higher level. That was really helpful."

Tracy explains, "The programs have definitely changed how I teach. It is more individualized. In the past, I would use Khan Academy, and the students could hear it from somebody other than me all the time. Different people prefer different types learning opportunities. Sometimes they listen to somebody else explain it or watch a video and bam, they understand it. Or when trying something and they get it incorrect, so they try it over and, 'Oh, epiphany, I just got it. I understand it now.'"

The implementation of CAI programs has changed how teachers can provide individualized instruction. Personalization is increased as students use the program and students are provided with different learning opportunities. The programs serve as another tool that teachers can use to help students learn required content.

Teacher trust in and deference to programs. Inferential coding of descriptive themes and interview transcripts helped construct a theme describing teachers' placement of trust in programs to engage students with appropriate learning activities and assessments built around required content standards. Teachers reported the need to audit the programs' lessons as they have found all content standards are not addressed at every grade level. Some teachers defer to programs to provide select learning activities or to direct the teacher-led portions of whole-class instruction.

Teachers defer to programs to provide lesson structure, content and select learning activities. Four of the seven teachers incorporate a program into their lesson structure and use the program as a guide for their daily math instruction. Two teachers forgo leading certain learning activities if the concepts are covered by the program. Yet, teachers expressed the belief that the teacher needs to be the educational leader in the classroom and the programs are situated as additional tools.

Erica shares, "Zearn has definitely changed how I teach. If the topic is relatively new, I will actually do the math chat, the actual instruction part with them, I project it.

Then we will do the actual scripted part of the lesson. It has given me more tools to use." She goes on to explain, "It is a little scary to think that they could just really get what they normally get from me while studying at the computer. Not the small group, but they work with instant feedback in a language that is friendly to them. Especially the higher students, I feel they could really be independent."

Melissa says, "Zearn, basically teaches the lessons also. The program takes them through all of the pieces of exactly what we are doing in class, and that is why I have them using Zearn a lot of the time. My students are getting a double dose of the lesson, from me teaching it and the computer teaching it. That has made a difference in how I teach because I try to make sure that our pieces are matching. If I am using certain vocabulary, I am making sure the class lesson and computer lesson match." She adds, "It is really easy to sometimes let the computer take over, and I don't want that…so it's finding the balance."

Teachers trust that the programs will provide the appropriate content aimed at grade-level standards. Amelia shares, "It is nice to know that if they get on this program, it is going to be exactly where they are supposed to be at without too much additional work on my part." Teachers also identify gaps in standards covered by adaptive programs to ensure students learn the required content. Julie says, "I pay attention to what they do not do on the programs because there are certain standards that DreamBox does not cover. That is important for me to know because I know that they are not going to review in those subjects."

Teachers incorporate programs into their lesson structure and use the programs to guide daily math instruction yet retain the belief that the teacher needs to be the educational leader in the classroom. Teachers using adaptive-programs rely on the programs to autonomously engage students in learning. Some teachers also defer to programs to guide whole-class daily instruction by using program-made lesson plans and presentation materials.

Teacher role shift from learning facilitator to program assigner. Pattern coding of descriptive themes was used to identify teachers' accounts of their experiences, resulting in a description of a degree of role shift from teacher as learning partner or leader to one who assigns programs to students, potentially diverting time and energy to ensuring student compliance with program use. Four of the seven teachers express a lack of student engagement in the programs after repeated use, situating the teacher as a director of program use over a leader of learning. Two teachers disclosed that students who are not engaged with the programs will click their way through the program, in and out of different lessons, occasionally working on problems that are several grade levels below their abilities. Less rigorous CAI tasks can create negative effects on mathematical relationships between a teacher and students as the programs fail to engage students in meaningful ways. In this circumstance, a teacher is positioned as an assigner of program use more than a facilitator of learning.

Lynn explains, "I think sometimes if I depend on the technology too much I would not be able to relate with the students mathematically. If I focused only on computer programs to teach them math, I think the relationship and the conversation would be missing… This year my relationship is not as good with my students mathematically whereas in the past, like last year it was really good. I am trying to focus a lot more on the adaptive math, but then it is more of me directing them on the computer and not that personal interaction that they need in order to relate to math."

Erica shares, "It is a little scary to think that they could just really get what they normally get from me while studying at the computer. Not the small group interaction, but with the program, they work with instant feedback in a language that is friendly to them."

Melissa relates, "Finding that balance is probably one of the more important aspects when it comes to using these programs. It is really easy to sometimes let the computer take over. 'Oh, it can teach them a little bit of this. I will just do this game over here or this.' And I do not want that, so it is finding that balance between the two."

Amelia describes, "Students are beginning to click in and click out because they have that option, and there are many different things they can choose from. Actually, completing their task, working on perseverance is something the students need help with."

Teachers perceive low student engagement in some programs after repeated use, situating the teacher as a director of program use over a leader of learning. Less challenging CAI tasks can negatively impact mathematical student-teacher relationships when programs do not engage students. In these circumstances, teachers feel positioned as an assigner of programs rather than a facilitator of learning.

Teacher as classroom and instructional leader. Values coding revealed that four of the seven teachers believe students need teacher-led direct instruction to learn and do not relinquish this role to the program. Categorical aggregation of themes related to teacher role intersects these findings, as teachers lead instruction and also assign CAI programs. In these circumstances, teachers' position adaptive programs as additional support and practice meant to compliment in-class lessons.

Katherine shares her belief in the need of a strong classroom and educational leader, "They need a really good leader who direct instructs them, teaches them how to self-assess, be aware of where they are in their learning process and lead them to that ownership and accountability."

Lynn shares her perception of student preferences of her instructional leadership and teaching over adaptive programs. "Sometimes, I think the students use Zearn and MobyMax as a brain break because the face to face instruction is so rigorous. In my instruction, I use with Engage New York; there is a lot of conversation and a lot of comparing answers and a lot of working together. I think in classes past that I have taught, they have preferred that over the computer-assisted."

Julie expresses her role as the classroom leader, "I am the boss of what they are learning. The programs are just for review or bulking up what they already know, so I do not feel it is directing me at all on what the students do."

Teachers described the necessity of a teacher that operates as and is seen as a leader of the class. As such, teacher-led direct instruction is given priority to CAI, and teachers do not concede their role of lead instructor. Computer-adaptive programs, in these circumstances, serve as additional supports, providing concept practice that compliments in-class lessons. Classroom observations confirmed the teacher as leader role and direct instruction was seen in all observations.

RQ2: How do teachers perceive their student-teacher relationships through the implementation of computer-adaptive instruction programs?

Through analysis of the participant interview and observation data, three main themes emerged to describe student-teacher relationships: Teacher proximity, communication, and support. Teacher proximity is further described by three sub-themes relating to teacher monitoring of program use, physical student-teacher proximity, and data use when programs are used separate from class time. Communication is further described by two sub-themes relating to social interaction being primary for learning, and teacher-student communication being informed through program use. The theme of support is broken into four sub-themes relating to program data and teacher accessibility, student engagement with programs, and technology issues. Each broad theme and supporting sub-theme is described and related to teachers' experiences.

Proximity. Descriptive and pattern coding of teacher interview transcripts revealed that teacher proximity to students during CAI program use ranges from close to distant and is experienced in varying duration and frequency. Observation data confirmed that teachers are in *close proximity* to students in a teacher-led small-group, often sitting at the same table or within a few feet of one another, cooperatively interacting with one another. Close teacher-student proximity assumes teacher-availability is concurrent with the proximity. In the absence of teacher-availability, close proximity as a factor of student-teacher relationships is negated. Observations of student-teacher distance and interaction during CAI use help define *distant proximity* as a student-teacher separation distance greater than five feet with minimal to no contact between students and teachers. Students spend an average of twenty to forty minutes of class time using CAI programs and five to twenty minutes working with the teacher in a small group. Students using an adaptive program are in close proximity to the programs in which they engage, and distant from the teacher.

Teacher monitoring of student program use allows for increased communication. Two of the seven teachers closely monitor their students using the program allowing them to use the program as a prompt for student-teacher communication. Lynn says, "I am constantly walking around the room, interacting with the students, especially with TenMarks being able to look at what they are doing and helping them one-on-one, sitting down with them one-on-one." Classroom observation of Erica working with her students highlights this monitoring and personalized assistance provided by the teacher.

Computer-adaptive programs allow for proximal student-teacher interactions at teacher-led centers and create student-teacher distance at computer-adaptive stations. Personal interactions between teachers and students are inherent to the nature of teacher-led small-groups. Teachers describe meeting with students that are struggling with class topics and providing one-on-one interactions to support student learning. She adds, "I can have students at the end of the day working independently on DreamBox and pull the students that are struggling with any topic in class. It gives me a chance to interact with them one-on-one and in small groups while the others are working at their levels." Through these small groups, teachers are able to interact in close proximity with students to support learning.

Teachers trust the program to engage students distant from the teacher appropriately, so the teacher may interact more closely with another set of students. This is highlighted by Amelia, "If students get on this program, it is going to be exactly where they are supposed to be without too much additional work on my part." Melissa agrees, "It actually helps to have them on the programs because I can work with the smaller group versus working with the whole group all the time."

Teachers also express their reliance on CAI programs to engage and occupy students. Julie explains, "When they are using the programs, it is a time when I am not with them, so I do not keep my thumb on them to follow the instructions." Julie's experience shows the need for teachers to be able to trust that a CAI program will keep students either engaged or occupied so the teacher can interact with someone else.

These views show how teachers maintain close proximity to the students within their small group yet remain distant from the students at other stations. Teachers will occasionally leave their small groups physically or verbally to redirect students or provide technical assistance with the programs.

Teachers are less likely to incorporate data from a program used outside of the classroom. Four teachers have their students use a CAI program in a math lab, away from the teacher; all of those teachers did not use student data from the program to inform curricular decisions or foster student-teacher interactions. Erica says, "DreamBox has reports, but I do not know that most of the teachers look at them because it is an extra thing, really." Lynn relates, "Even though they use DreamBox without me in the math lab, I can access that information, it is just finding the time to do it. There is not much time in a grade school prep period to access all the information you need for reading, writing, and math. To me, it is tough to take the time to do that." Data may be inaccessible to teachers stemming from time constraints or training needs.

Communication. Values coding of participant response data revealed that teachers believe learning happens through and as a result of communication with those around them. Value is placed on the teacher as a classroom leader and instructor, that can facilitate discourse with and among students. Computer-adaptive programs are viewed as helpful to teacher-student communication through data informed interactions and a hindrance to communication with students using programs with low levels of engagement.

Social interaction is primary over program interaction for student learning. Three of the seven teachers explicitly described best student learning as a result of interactions with others, positioning CAI programs as a support for learning that cannot replace essential interpersonal interaction. Katherine postulates, "I think children need people and we need to learn from each other. I think language skills are learned through collaboration. I would say using DreamBox has not changed how I teach in that regard. I think you learn from your teacher, but you learn most from your peers, quite honestly." Lynn relates with her experience, "It is good at some points for practice, but to teach in rigor and to teach in those conversations using mathematical language, they need to have that academic discourse in order to understand and trigger that part of the brain. I think the most success I have with students understanding math is when we have conversations." If CAI programs are to be used wholly, Lynn adds, "If the developers of these programs were to change anything, they need to have a component where the students can have a discussion within the technology. Especially if they are moving to where the teacher uses this exclusively somehow, it needs a place where the students can have chats not just with the computer programmer at the other end, but where they can have that conversation with each other… That conversation is so important in understanding math." These views highlight how teachers' beliefs that social interaction is foundational to student learning are met with realizations that computers and programs are part of modern students' lives.

Program informs teacher-student communication. Teachers describe teacher-student communication informed by adaptive-program generated data. According to Amelia, "Using the program probably increased my communication with students because I go back and check pieces of the data and let them know where they stand. It also lets me know if they are completing as many lessons as they should each week so I can keep track. Especially since we have computer-adaptive time built into one of our specials at the math lab, it is important that they are actually working during that time. It has increased communication regarding on task or where their challenges are, and it allows students to let me know how they are feeling about it or what they are struggling with." Teacher-student communication benefits when student data inform conversations and support.

Support. Categorical aggregation of descriptively-coded data identified a broad theme of student support. Both teachers and CAI programs provide student support. Teachers describe adjustments in their support to students based on information from student experiences with the programs. Both the teachers and programs provide feedback to students, and student data generated from a program may inform teacher-delivered feedback. Support to students can be compromised when actionable student data are inaccessible to teachers or when technical issues arise.

Program data can inform and increase teacher-student feedback. Three of the seven teachers describe increased feedback opportunities around student struggles directly from CAI program use, leading to student support and productive learning communication. Erica says, "As far as having these programs impacting my relationships with students, it is just the data in general that helps. I can pull a group of three because they did not understand that you need to carry when you are three-digit adding or something like that. I can get more targeted instruction to them based on that information." Increased feedback opportunities based on student data from CAI programs enhance student support.

Four of the seven teachers expressed a change in their relationships with their students through the implementation of CAI. Teachers expressed benefits to their relationships stemming from opportunities for increased teacher-student feedback. Amelia says, "The program is a way of increasing that communication, that feedback." Erica shares, "Just having that information at your fingertips to make those groups for intervention or extension is much easier than processing the data all on your own."

Additionally, programs provide their own feedback to students. Katherine notes, “For sure, the program gives them instant feedback, and that is good.”

Lynn’s experience contrasts teachers’ perceived benefits to student-teacher relationships, “This year my relationship is not as good with my students mathematically whereas in the past, like last year it was really good. I am trying to focus a lot more on the adaptive math, but then it is more of me directing them on the computer and not that personal interaction that they need in order to relate to math.”

These findings support the idea that each classroom has unique teacher and student combinations that lend to varied learning interactions and opportunities for feedback and support. Teachers expressed changes in feedback through the implementation of CAI as a beneficial component of their relationships with students. Benefits to relationships stem from opportunities for increased teacher-student feedback. Conversely, program use may give the perception of students as disconnected from their teacher or disinterested in learning. In this circumstance, the program does not enhance feedback but appears to impeded student-teacher discourse.

Rigor of computer-adaptive tasks can affect student-teacher interactions. Three teachers note that student-teacher communication benefited in the presence of a CAI program that presented rigorous tasks that necessitated student-teacher communication.

Lynn explains, “When I used TenMarks last year, it affected how I interacted and communicated with students. TenMarks was intensive, and the students would often ask me questions. I would be able to walk around the room and see what they were working on to help them with it. Since the problems required processing and figuring out, and they had to solve it on paper with a pencil. I could actually see what they were doing to help them. With Zearn and MobyMax, they are just doing it in their head, and there is not a lot of rigor. The programs that the students are using this year are not as rigorous as last year. If it is more rigorous, then there is definitely a lot more communication, but if it is something that is too simplistic, then I do not have that interaction." If appropriately-rigorous CAI mathematical content is provided to students, student-teacher relationships have shown to benefit in proximity, communication, and support.

Data can positively impact teacher ability to provide support, if accessible and actionable; teachers note training and time needs. Two of the seven teachers describe enhanced assessment and data from the programs from which to base instructional decisions. When the CAI program is designed to pair with the daily classroom lessons, teachers are able to adjust the communication and support of a lesson based on program data. Teachers can also assess student interest and engagement in the programs via user statistics.

Amelia stated, "You can check and see if they were not interested in it, or if they did not understand it. Also, you know if they have failed it several times and then you can go back and reteach. If you have missed that within your progress monitoring, this is another tool." Erica relates, "I can get more targeted instruction to them based on that information. The programs definitely changed how I provide support to students with the intervention groups." Computer-adaptive programs that are incorporated into daily classroom objectives allow teachers to adjust the communication and support of a lesson based on program data. Teachers also assess student interest and engagement in the programs via user statistics.

In contrast, two teachers describe the data from some CAI programs to be too vague to help with student-teacher communication for learning. Lynn relates, “I can give the students feedback like if they have passed so many lessons, you get a B, but it is not feedback on what they are strong at or what they need to work on. There is none of that information specially to let me know, ‘Okay, this is their strength. This is their weakness. Focus on this’… To me, I cannot use that to communicate with them. I may find out that a student did five lessons, but that doesn't help me help them.” This shows a need for CAI data and associated reports need to be accessible and useful if teachers are expected to take advantage of them.

Two of the seven teachers express the need for more training on how to use the programs to provide student feedback and modify student control of certain program choices. This highlights the need to ensure proper training accompanies implementation. Katherine says, “I do think DreamBox could provide better services in regard to making sure teachers know how to utilize the reports and how to navigate setting up assignments. Part of that I recognize is a time thing. When you are teaching all subjects in a self-contained classroom, every ounce of your time really needs to be meaningful and targeted at students. You really do not want it to be a wasted time, sadly, and I say that very carefully because I really do want to believe in it. But they need to provide better support.” Lynn shares a similar experience, “I do not know where the information is for me to see feedback on my students except for the number of lessons they get. To me, I cannot use that to communicate with them."

These experiences highlight the need for accessible and useful student data to inform teacher-delivered support to students. Some teachers expressed the need for additional time and training and to make data useful and other teachers prefer to learn on their own at their own pace. More specific data and suggestions provided to teachers are more useful than general usage statistics and concept pass rates. Detailed data allows teachers to form ability groups and address specific students learning needs.

Technology issues detract from supports to student learning. Technology issues consume time that the teacher could use to spend working with students. During these experiences, student learning support is compromised at both the CAI and teacher small-group locations. As a teacher assists with technical issues related to computer dysfunction or malfunction, students do not receive learning-based support from the teacher or computer. Katherine relates, "…all of sudden they could not do any work on the program, and I had to make some changes. When you are dealing with 23 children, and you are trying to do flexible groupings, those are just the little nuisance that I do not want to have to deal with. I want it to work…" A classroom observation of Julie and her students demonstrated the added challenge presented to a teacher when technical issues arise. Julie needed to leave her teacher-led small-group multiple times to assist with new student logins to an adaptive program, sacrificing students' time with her small-group-based personalized support.

Learning time is not maximized when a piece of a CAI system does not function properly. The malfunction may result from issues ranging from user login errors to computer hardware and software compatibility to internet service outages. No matter the source of the problem, technical issues are evident in classrooms using computers and these issues impact student learning support.

Summary

This chapter presented teachers' perspectives and experiences implementing CAI programs into their classrooms. The findings from interviews and observations were discussed in relation to teacher role and student-teacher relationships. Inductive analysis through first and second cycle, descriptive, values, and pattern coding resulted in eight major themes related to teacher role and student-teacher relationships through the implementation of CAI programs. Five themes emerged to describe teacher role: Teachers as personal instructors, individualized instruction, teacher trust in and deference to programs, role shift from learning facilitator to program assigner, and teacher as classroom and instructional leader. Three primary themes emerged related to teacher relationships: Teacher proximity, communication, and support. Further analysis and discussion of these findings are carried out in the next chapter. Implications and recommendations for future research are also discussed.

Chapter Five: Discussion

This chapter reviews the previous four chapters, then presents the analysis, implications, and recommendations from teachers' experiences of CAI program implementation. With the growth of 1-to-1 computing environments, the dynamics within classrooms are shifting (Bebell & O'Dwyer, 2010). As instruction moves from teacher-created-and-delivered to computer-driven lessons and feedback, attention should be paid to how CAI programs impact relationships between students and teachers. This study fills an existing gap in the literature by exploring the changes taking place within classrooms that have implemented modern CAI and identifying how teacher role and student-teacher relationships are affected or modified.

In response to the consistent increase of classroom computer integration and proliferation of CAI learning programs in K -12 schools, this study examined teachers' perceptions and experiences of CAI program use and provides insights to help understand the dynamics that do or do not occur throughout program implementation. Specifically, this study captured elementary teacher perceptions of their role and relationships with students through the implementation of computer-adaptive math programs. With this knowledge, educators and education leaders will be better informed when choosing to enter or not to enter the world of CAI. This study answers the following research questions:

1. How is teacher role impacted through the implementation of computer-adaptive instruction programs?

2. How do teachers perceive their student-teacher relationships through the implementation of computer-adaptive instruction programs?

Relevant literature around the increased use of technology in education, the design and use of modern CAI programs that are built to meet the individual needs of students, the role of the classroom teacher and the factors that comprise relationships between teachers and students have been presented. This literature formed a baseline from which to study the effects of CAI programs on the interactions between teachers and students.

A qualitative research design was used to obtain teachers' perspectives on experiences with CAI programs within their classrooms and relationships with their students. Inductive analysis was performed because teachers' perceptions of these newly implemented technology programs are unknown, and this research sought to describe and understand the experiences currently taking place in classrooms. This work sought to understand the elementary teachers' world and their work within that world as it examined teacher-student interactions as described by the teacher, with a focus on teacher role and relationships. Qualitative interview and observation data were collected, coded, and analyzed.

Interview data were collected from seven teachers in two elementary schools and were synthesized with observations of five of the teachers' in their classrooms to develop eight major themes. In addition to common themes, interview narratives, observation data, and researcher interpretations are included in to help illuminate the unique experiences and perspectives of each teacher. Five themes emerged to describe teacher role: Teachers as personal instructors, individualized instruction, teacher trust in and deference to programs, role shift from learning facilitator to program assigner, and teacher as classroom and instructional leader. Three main themes emerged to describe student-teacher relationships while using commuter-adaptive programs: Teacher proximity, communication, and support.

This chapter will interpret these findings using Actor-Network Theory as a framework to understand the connections between students, teachers, and adaptive-programs as they relate to teacher role and student-teacher relationships. Implications for practice and recommendations for further study will be discussed.

Impacts of computer-adaptive program implementation on teacher role and student-teacher relationships

The findings in this study support an understanding that each classroom has unique teacher and student combinations that lend to a variety of expressions of student-teacher relationships. Teachers that place trust in a program to suit students' needs see opposing relational outcomes. A teacher who pushed a non-engaging adaptive-program to her students experienced student-teacher disconnect, negatively impacting her relationships with her students. In contrast, teachers who perceive their students as engaged with adaptive-programs expressed comfort in knowing students receive appropriate computer-based instruction and appreciate the opportunity to have non-computer-based interactions with students in small-group settings.

Computer-adaptive program implementation's impact on teacher role is pronounced through teacher positioning as a small-group instructor with the ability to individualize instruction. As students use adaptive-programs, they are autonomously occupied with the program, allowing teachers to capitalize on time to work with select students more intimately. In addition, teacher role can shift from a facilitator of learning to an assigner of programs when students display low engagement with the programs.

Student-teacher relationships are impacted by program-generated student data that can assist teachers with student communication and support. Student-teacher relationships are impacted by student-teacher proximity while teachers acutely interact with students in teacher-led small groups. Communication and support can be impeded by student non-engagement in adaptive-programs, leading to a potential lack of communication or teacher role-shift away from learning facilitator toward program assigner.

Theoretical Model Application

Actor-Network Theory is applied to teachers' perceptions of computer-adaptive classrooms to model the unique and combined interactions of students, teachers, and adaptive-programs. Actor-Network Theory situates students, teachers, and a CAI program as actors in an interconnected network; each actor having its own capacity to act, react, and interact with the other actors in the network. Analysis synthesizes teachers' experiences in student-teacher-program classroom networks and positions each actor as having effects on teacher role and student-teacher relationships.

Themes related to teacher role and student-teacher relationships were analyzed applying ANT and sorted categorically according to relations among actors. Students, teachers, and CAI programs were each involved in six combinations of interaction between network actors. Considerations of connections between students, teachers, and programs are described by the eight major themes of teacher role and student-teacher relationships.

All three actors in the student-teacher-program relationship can interact and influence each other bidirectionally within the computer-adaptive classroom network. Students, teachers, and programs impact one another as the computer-adaptive-classroom network, with implications for teacher role and student-teacher relationships. Figure 3 depicts the computer-adaptive classroom network.

Figure 3. Computer-Adaptive Classroom Network

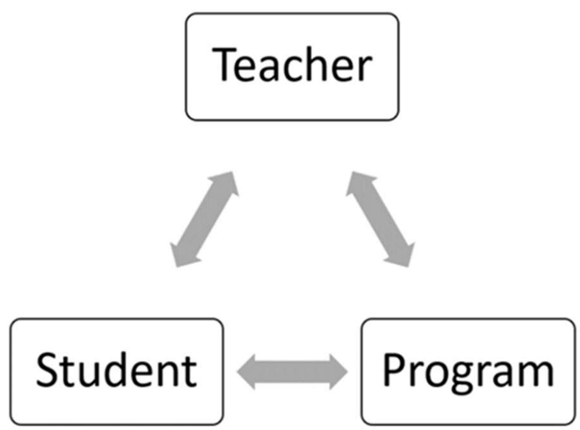

Figure 3. Actor-Network Theory situates teachers, students, and programs as autonomous actors with the capacity to interact and impact one another, comprising a network.

RQ1: How is teacher role impacted through the implementation of computer-adaptive instruction programs?

Connections between teachers, students, and programs are modeled with the Actor-Network Theory in Figure 4.

Figure 4. Teacher Role in the Computer-Adaptive Classroom Network

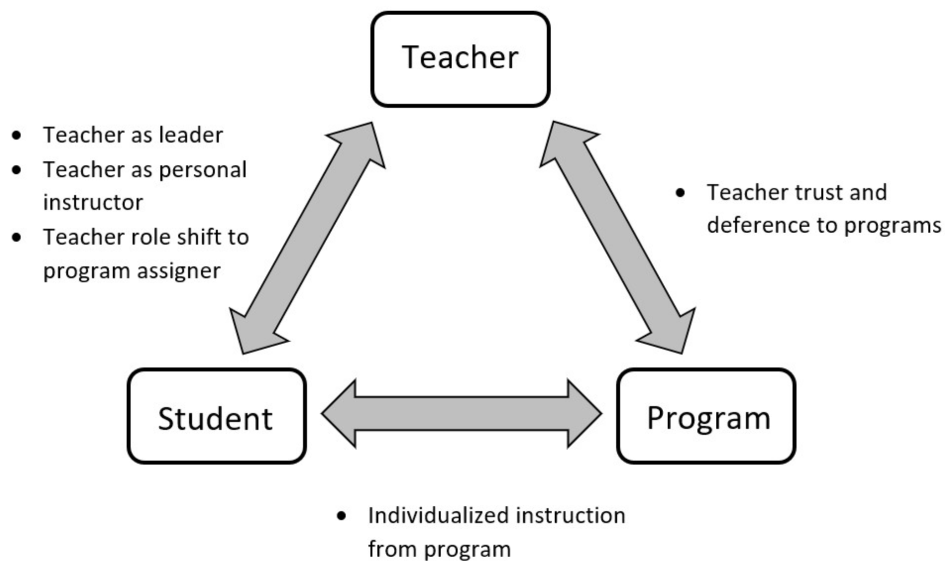

Figure 4. Themes of teacher role framed through connections between computer-adaptive classroom network actors.

Teacher-student connections. Four themes of teacher role stem from the student-teacher connection in the adaptive-classroom network.

Teachers are situated as personal instructors during a fraction of students' math time, in a Flex or Station Rotation model. Computer-adaptive program use enhances the ability of teachers to implement learning centers by autonomously and independently occupying students. The teachers trust the program will engage students so that the teacher may work with other students either through a station rotation or flexible grouping and timing arrangements known as a Flex model. In a station rotation, teachers interact with students in small groups for 10 - 20 minutes during a typical math session; students interact with adaptive-programs for 20 - 60 minutes per day, more than doubling the average daily small-group student-teacher contact time during mathematics.

Individualized instruction from teachers and programs. Teachers can be situated to interact with students on a one-on-one and small-group basis when CAI programs are in use, and both teachers and CAI programs provide individualized instruction for students. Teacher-led small group instruction was shown to be informed by student program data when adaptive-programs were integrative with daily class lessons.

This was noted by Lemke (2013), as proponents of adaptive learning programs point to personalized student learning experiences with self-controlled pacing, content, and environment. Proponents say that the possibilities for differentiation and personalization allow teachers to connect on a deeper level with students because they know their strengths and needs in a more detailed way.

Results of this study confirm the notion of teachers being provided with more detailed information about student strengths and struggles will lead to opportunities for different connections between teachers and students. However, this was only confirmed in situations where teachers had students use CAI programs that were integrated with daily lesson objectives.

Teacher as classroom and instructional leader. Teachers described the necessity of a teacher that operates as and is seen as a leader of the class. As such, teacher-led direct instruction is given priority to CAI, and teachers do not concede their role of lead instructor. Computer-adaptive programs, in these circumstances, serve as additional supports, providing concept practice that compliments in-class lessons or student-leveled topics.

Teacher role shift from learning facilitator to program assigner. Perceived low student engagement in programs situates the teacher as a director of program use over a leader of learning. Less rigorous and non-engaging CAI tasks can negatively impact mathematical student-teacher relationships. In these circumstances, teachers feel positioned as an assigner of programs rather than a facilitator of learning. This is supported by similar findings in a case study by Lopez-Boren (2016) where teachers implementing adaptive programs felt that their role had shifted away from a partner in learning and toward an enforcer of program use.

Program-student connections. One theme of teacher role from the program-student connection in the adaptive-classroom network was found.

Individualized instruction from teachers and programs. Programs are situated to interact with students one-on-one and provide individualized instruction and feedback. The program provides instructional activities that elicit student input and generates feedback for students and lesson trajectories.

Teacher-program connections. One theme of teacher role stemming from the teacher-program connection in the adaptive-classroom network was found.

Teacher trust in and deference to programs. Teachers using adaptive-programs place trust in the programs to engage students with appropriate learning activities and assessments built around required content standards. Teachers incorporate programs into their lesson structure and use the programs to guide daily math instruction, yet retain the belief that the teacher needs to be the educational leader in the classroom. Teachers using adaptive-programs rely on the programs to autonomously engage students in learning. Some teachers also defer to programs to guide whole-class daily instruction.

With teacher deference to CAI programs, students can make connections among teacher-led and program-led learning activities because daily teacher-led and computer-adaptive lessons are aligned. This allows teachers to link teacher-student daily lesson communication with student-program experiences to help support student learning.

RQ2: How do teachers perceive their student-teacher relationships through the implementation of computer-adaptive instruction programs?

Figure 5 summarizes the connections between teachers, programs, and students as they relate to student-teacher relationships.

Figure 5. Student-Teacher Relationships in the Computer-Adaptive Classroom Network

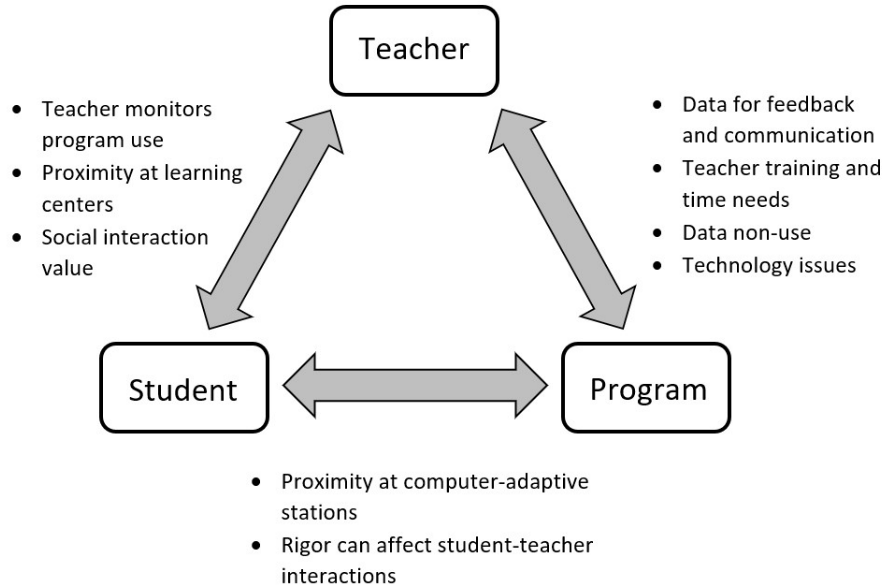

Figure 5. Themes of student-teacher relationships framed through connections between computer-adaptive classroom network actors.

Teacher-student connection. Teacher-student connections in the adaptive-classroom network describe student-teacher relationships in themes of student-teacher proximity and communication.

Teacher monitoring of student program use allows for increased communication. Two of the seven teachers closely monitor their students using the program allowing them to use the program as a prompt for student-teacher communication. Lynn says, "I am constantly walking around the room, interacting with the students." This is contrasted by a majority of participating teachers who do not closely monitor their students during computer-adaptive use.

Computer-adaptive programs allow for proximal student-teacher interactions at teacher-led centers and create student-teacher distance at computer-adaptive stations. The automated nature of a student-program connection is logistically integral to the creation of time for teachers to meet with students around unique educational needs. This demonstrates that distant student-teacher proximity and low student-teacher connection are necessary for other students to experience proximal interactions with teachers in small groups or one-on-one.

Wubbles and Brecklemans (2005) describe teacher proximity as more than mere physical distance but rather a continuum from opposition to cooperation, and a teacher positioned in high proximity, or cooperation, to students with a high degree of influence contributes to effective student-teacher relationships. Teachers meet with students that are struggling with class topics and providing one-on-one interactions to support student learning. Through these small groups, teachers can interact cooperatively with students to support learning. With the assumption that close proximity assumes teacher availability, these findings are supported by Leitao and Waugh's (2007) determination that teacher availability is a key factor of student-teacher relationships.

As teachers maintain close proximity to students within their small group, they remain distant from other students and therefore, trust the program to engage students distant from the teacher appropriately. Teachers will occasionally leave their small groups physically or verbally to redirect students or provide technical assistance with the programs.

Social interaction is primary over program interaction for student learning. Teachers explicitly described best student learning as a result of interactions with others, positioning CAI programs as a support for learning that cannot replace essential interpersonal interaction. Teachers' beliefs that social interaction is foundational to student learning are met with realizations that computers and programs are part of modern students' lives. Teacher beliefs in the necessity of communication for learning are supported by Social Development Theory (Vygotsky, 1978), recognizing that students develop cognitively, as a result of social interactions.

Program-student connection. Two sub-themes of proximity in student-teacher relationships were found via the program-student connection in the adaptive-classroom network. Program-student connections in the network are explained in two sub-themes of student-teacher proximity.

Computer-adaptive programs allow for proximal student-teacher interactions at teacher-led centers and create student-teacher distance at computer-adaptive stations. Teachers meet with students that are struggling with various topics and providing one-on-one interactions to support student learning while trusting a program to appropriately engage students distant from the teacher appropriately. Observation data revealed that teachers using a station-rotation of Flex model were shown to occasionally engage with students using the programs to provide redirection or provide technical assistance. Wubbles and Brecklemans (2005) noted that high student-teacher proximity, or cooperation, can strengthen student-teacher relationships, providing a point to consider for teachers implementing CAI programs. Teachers could benefit from keeping an awareness of the nature and extent of their proximity to students when CAI programs are in use.

Rigor of computer-adaptive tasks can affect student-teacher interactions. Student-teacher communication benefited in the presence of a CAI program that presented rigorous tasks that necessitated student-teacher communication and identified student support needs. If appropriately-rigorous and engaging computer-adaptive mathematical content is provided to students, student-teacher relationships have shown to benefit in proximity, communication, and support. In contrast, less rigorous and less engaging computer-adaptive content resulted in teacher-student communication to ensure student compliance with program use rather than communication for learning.

Teacher-program connections. The theme of communication and three sub-themes of support to student-teacher relationships via the teacher-program connection in the adaptive-classroom network were found.

Program informs teacher-student communication. Teachers describe teacher-student communication informed by adaptive-program generated data. Teacher-student communication benefits when student data inform conversations and support.

Program data can inform and increase teacher-student feedback. Teachers described increased feedback opportunities around student struggles directly from CAI program use, leading to student support and productive learning communication. Student data from CAI programs were described to enhance student support when the computer-adaptive lessons were rigorous and integrated into the daily classroom lessons. This suggests that CAI programs that integrate with classroom lessons can support communication that transcends between the computer and the classroom; communication that ties computer and classroom learning together.

Teachers also expressed this change in feedback through the implementation of CAI as a beneficial component of their relationships with students. Benefits to relationships stem from opportunities for increased teacher-student feedback. Conversely, program use may give the perception of students as disconnected from their teacher or disinterested in learning. In this circumstance, the program does not enhance feedback but appears to impede student-teacher discourse. Each classroom has unique teacher and student combinations that lend to varied learning interactions and opportunities for feedback and support.

Data can positively impact teacher ability to provide support, if accessible and actionable; teachers note training and time needs. Enhanced assessment and data from programs form a basis for instructional decisions. Computer-adaptive programs that are incorporated into daily classroom objectives allow teachers to adjust the communication and support of a lesson based on program data. Data from some CAI programs are too vague to help with student-teacher communication for learning. A need exists for computer-adaptive data, and associated reports need to be accessible to teachers via training and time if teachers are expected to take advantage of them. Teachers who did not feel prepared to utilize the programs fully also feel that the programs have not changed their teaching in any way. This is supported by Jude et al. (2014) who note the primary reason for non-use of education technology is teachers' lack of know-how on using particular hardware or applications. Handal et al. (2013) rationalized that teachers need specific training in working with online tools and digital learning resources to maximize the use of learning technologies.

Teachers are less likely to incorporate data from a program used outside of the classroom. Teachers whose students use a CAI program in a math lab, away from the teacher did not use student data from the program to inform curricular decisions or foster student-teacher interactions. This highlights a missed opportunity for CAI program use to directly enhance classroom learning through improved communication or support.

Technology issues detract from supports to student learning. Technology issues consume time that the teacher could use to spend working with students. During these experiences, student learning support is compromised at both the CAI and teacher small-group locations. As a teacher assists with technical issues related to computer dysfunction or malfunction, students do not receive learning-based support from the teacher or computer.

Limitations and Delimitations

This study was time-bound by the 2017-2018 academic school year. Semi-structured participant interviews took place in the first semester of the school year and required teachers to reflect upon prior years' experiences with and without CAI and relate them to current classroom experiences. Interviews were transcribed, coded, and qualitatively analyzed in the first and second semesters of the school year.

This study has several limitations. It was confined to one school year, and the researcher asked participating teachers to reflect upon the current year and experiences during prior years. This study was also limited by the small number of participating teachers, all of whom self-selected to participate in the study. These teachers were involved in a pilot program, received training and had administrative supports available to them. Classroom observations only occurred one time and five of the seven participants were observed. Lastly, only the perspectives of teachers were sought to identify factors relating to student-teacher relationships. As such, this study is useful to ascertain perspectives on the experiences of teachers to be used by the educational community. However, generalizations about the use of CAI programs should be made cautiously.

Recommendations

Because this study utilized teacher perceptions and experiences without input from students, further study should focus on the perspectives and experiences of students as they shift toward using CAI programs. Student perspectives of student-teacher relationships in the presence of CAI programs would help researchers understand the realities of students using such programs.

Teachers expressed the notion that communication is essential for learning, supporting SDT and a constructivist approach to learning. Computer-adaptive program use can, however, be a behaviorist approach to teaching. Further study of these contrasting approaches to learning and how teachers integrate both interpersonal communication and program use would be beneficial.

Implications

The model derived in this study applies ANT to teachers' perceptions and experiences of CAI program implementation to create a framework for understanding teacher role and relationships in computer-adaptive classrooms. Schools and districts that desire to support positive student-teacher relationships and implement a CAI program may benefit from an implementation analysis stemming from this framework. Analysis can seek to understand teachers experience and comfort level with their role in assigning and promoting an adaptive-program and their ability to use data to inform proximal student-teacher communication. Implementation analysis would further elicit training or scheduling needs that would best allow teachers to maximize use of student data for individualized support. The analysis would highlight factors that are working well and identify those factors within the adaptive-classroom network that are in need of attention or support.

Program role as a provider of supplemental or integrated content. Computer-adaptive programs can be positioned as supplemental content providers or integrated content providers. Both roles will undoubtedly provide grade-level-appropriate, standards-based content to students. Both types of content providers impact teacher role and student-teacher relationships differently.

When programs are situated as supplemental content providers, individual student learning objectives are not designed to match the daily classroom lesson objectives. In this circumstance, the common learning communication in the classroom is not aligned with individual student lessons, situating programs as less an asset for increased communication or support from the teacher.

In contrast, when programs provide computer-adaptive lessons that align to daily classroom lessons, teachers and students have common language and models to share in discussions and general communication for learning. In these circumstances, teachers present whole-class lessons and work in small-groups and one-on-one with students around the same daily topics the CAI programs provide. This connection between program, teacher, and student is a support to student-teacher relationships through informed communication for learning.

Teacher role. Teachers position themselves as instructional leaders of their classroom regardless of deference to CAI programs. Teacher role as a leader can be supported when students view a program as having an educational purpose, is valued and has been assigned by the teacher. Teacher deference to programs that correlate with daily classroom lessons can allow for learning situations in which student understanding spans between teacher and program-led.

If teachers defer to programs that do not adequately engage students, teacher role can shift from classroom leader of learning to classroom leader of assigning. Additionally, lack of student engagement in programs can impede student-teacher communication for, a factor of student-teacher relationships.

Data impacts on teacher role and student-teacher relationships. Student data generated from CAI programs can inform teachers, helping them support student learning. Program data returns to students as feedback directly through the program and indirectly through teacher communication, decisions, and actions. Teachers were found less likely to utilize program-generated student data to provide student support when programs served as supplemental content providers and not integrated into daily classroom lessons. In order for student data to effectively return to students through the teachers, the data must be accessible.

Effective training can enhance teacher accessibility to program-generated student data or impeded by lack of such training. Access also hinges on the time allotted in a teachers' schedule to find, process, and utilize student data. Tondeur et al. (2013) noted that teacher training has been effective when teachers have been allowed to gradually gain ideas for integrating technology, then provide opportunities for teachers to share their experiences with colleagues.

Student data can inform teacher-student communication and support through ability grouping. Teachers describe using program data to group students by ability for small-group instruction. In these small groups, teachers connect with students at levels appropriate for student learning; some students receive more attention or different explanations than others.

Student data can inform individual conversations and support between a teacher and a student. Teachers express the ability to assess if students have knowledge gaps concerning grade-level standards. Teachers describe the ability to use that information to work with students to address misunderstandings or provide more instruction.

Conclusions

Classroom computer integration and the proliferation of CAI programs in K -12 schools is steadily progressing. At the same time, academic success, as well as the social and emotional well-being of students, is critical in American schools. The integration of CAI programs into America's elementary classrooms impacts the role of the teacher and relationships between teachers and students, placing a priority on the study of these programs and their effects. This study fills an existing gap in the literature by exploring the changes taking place within classrooms that have implemented modern CAI programs and identifying how teacher role and student-teacher relationships are affected.

This qualitative study examined teachers' perceptions and experiences of CAI program use and found eight major themes that provide insight to help understand the dynamics that are occurring in today's elementary computer-adaptive-classrooms. Five themes emerged to describe teacher role: Teachers as personal instructors, individualized instruction, teacher trust in and deference to programs, role shift from learning facilitator to program assigner, and teacher as classroom and instructional leader. Three main themes emerged to describe student-teacher relationships while using commuter-adaptive programs: Teacher proximity, communication, and support.

Elementary teacher perceptions of their role and relationships with students through the implementation of computer-adaptive math programs have been used to model the connections between teachers, students, and programs within classroom networks. With this knowledge, educators and education leaders will be better informed when implementing or choosing not to implement CAI.

Characteristics of traditional teacher roles can change with the implementation of CAI programs, fluctuating among a leader of direct-instruction to facilitating collaborative inquiry to an assigner of programs. The role of the teacher is intertwined with the nature of student-teacher relationships as relationship factors such as proximity, communication, and support can be supported through teachers' actions in their role as a leader, instructor, or facilitator.

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