HOW TEACHERS MAY INFLUENCE THE IMPACT OF COMPUTER ADAPTIVE INSTRUCTION:

A MIXED-METHODS ANALYSIS OF IMPLEMENTING LEXIA CORE5 IN SECOND-GRADE CLASSROOMS

by

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The following individuals read and discussed the dissertation submitted by student Scott G. Woolstenhulme, and they evaluated the student's presentation and response to questions during the final oral examination. They found that the student passed the final oral examination.

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DEDICATION

For my sweetheart and eternal companion, Lindsey.

I could never have gotten here without you.

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ABSTRACT

School districts across the country have been adopting computer adaptive instructional programs as early reading interventions. It is imperative to learn whether CAI has an effect on student reading gains and what other factors may influence its effect. This mixed methods study employed an explanatory sequential design to first evaluate the reading gains of 2nd grade students. An independent samples t test showed that 2nd grade students in 2017 who participated in the Lexia Core5 reading intervention program for at least 30 hours had significantly higher gains than their peers in the 2014, 2015, and 2016 school years. A multiple regression analysis was then used to identify what other factors may have influenced student reading gains. These factors included teacher-level factors including teacher evaluation score, teacher years of experience, and the mean percentile gain of each teacher's class, student-at risk factors, class-level factors including class size and program implementation level, and program-level factors including hours of participation and number of levels completed. Only the teacher's mean percentile gain and hours of participation were found to be statistically significant.

In the qualitative phase of the study, extreme case sampling was used to identify teachers who had exceptionally high gains on the Star Reading assessment. These teachers were interviewed to learn whether they shared common beliefs or practices. An action-coding analysis of the interviews showed that teachers shared the following practices: (a) using Lexia Core 5 to differentiate reading intervention, (b) publicly celebrating students' achievement in the program, (c) collaborating as grade-level teams

to provide more intensive interventions when necessary, and (d) frequently monitoring students' progress using the reports in the Lexia Core5 program.

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LIST OF ABBREVIATIONS

CAI	Computer-adaptive instruction or computer-assisted instruction.
FRL	Free / Reduced Lunch status. The primary indicator of a student's socioeconomic status. Students who are eligible for FRL are typically considered to be in poverty.
NAEP	National Assessment of Education Progress
NRP	National Reading Panel (2000)
ORF	Oral reading fluency. Typically, the number of words ready correctly in a one-minute timed passage.
SES	Socioeconomic Status
WCSD	Washington County School District, the subject of the research study.

CHAPTER ONE: INTRODUCTION

Background

In 2016, the Idaho State Legislature adopted House Bill 526 which expanded reading intervention programs for students in kindergarten through third-grades. This bill not only specified new mandates for reading intervention programs, but also required school districts to provide at least 60 hours of intervention for students who are significantly below proficiency benchmarks, twice the number of hours that were previously required. Such legislation is not unique to Idaho. In 2014, the Education Commission of the States reported that 36 states required early reading assessments and 33 also mandated intervention or remediation for struggling readers (Workman, 2014).

Efforts to improve literacy among American schoolchildren are not new: for decades, state and national efforts have sought to increase the percentage of students who become proficient readers before fourth-grade. In 1965 President Lyndon B. Johnson created the Head Start program to improve the number of those who could pass the military's basic skills entrance test (Fiester, 2010). The 1970s saw continued national efforts to increase literacy for American schoolchildren including the National Right to Read Effort, Reading is Fundamental, the Office of Basic Skills, Head Start, and the Title 1 Act (Chall, 1983). A primary goal of the National Right to Read Effort was to ensure that 99% of 16-yeard old students could "read well enough to function effectively" in society ("Resolution on federal support for the national right to read effort," 1971).

These efforts have achieved some success. Results from the National Assessment for Educational Progress (NAEP) showed an increase in mean reading scores from the early 1970s to 2012. In fourth-grade, students' mean reading score of 221 points was 13 points higher than their peers in 1971 as shown in Figure 1 below (National Center for Education Statistics, 2013). In spite of this improvement, however, the 2015 NAEP results also showed that only 36% of fourth-grade students could read at the proficient level, and 31% of fourth-graders could not read at the basic level (National Center for Education Statistics, 2016).

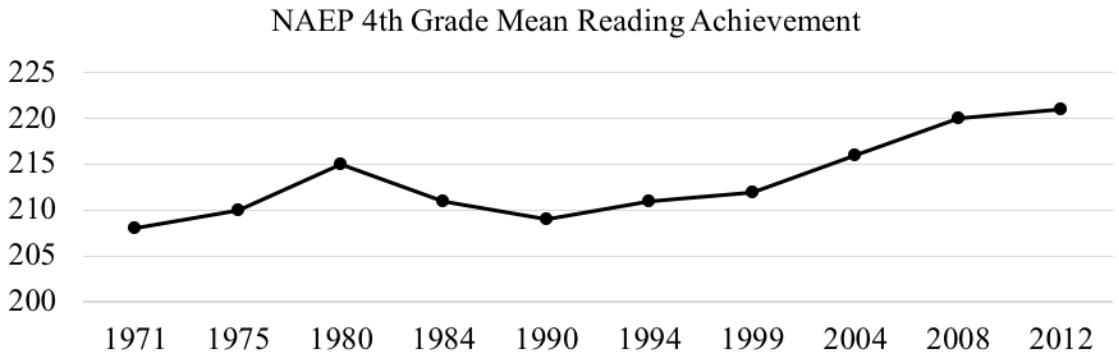

Figure 1. NAEP fourth-grade mean reading scores (1971-2012).

Data from the National Center for Education Statistics. (2013). *The nation's report card: Trends in academic progress 2012.* Washington, D.C.: Institute of Education Sciences, U.S. Department of Education.

For more than thirty years, research has consistently shown that students who do not become proficient readers by fourth-grade face significant challenges for their remaining years in school as well as their employment after graduation (Hernandez, 2011). In 2002, the U. S. Department of Education reported that "evidence strongly suggests that students who fail to read on grade level by the fourth-grade have a greater likelihood of dropping out of school and a lifetime of diminished success"(U.S.

Department of Education, 2002). This claim was substantiated in a longitudinal study of approximately 4,000 students showing that students who do not achieve reading proficiency before fourth-grade are four times less likely to graduate from high school on time. This risk is multiplied for students who have also experienced living in poverty (Hernandez, 2011).

Perhaps the key reason for the importance of achieving proficient reading skills before fourth-grade is that third-grade is a pivotal year in school as literacy instruction shifts from learning to read to reading to learn (Fiester, 2010; Hernandez, 2011). This shift requires students to use the reading skills they have learned "to think critically about what they are learning, and to act upon and share that knowledge in the world around them" (Fiester, 2010, p. 9). Hall, Hughes, and Filbert (2000) noted that because reading is the foundation of curriculum, students who do not learn to read will continue to experience difficulty in learning other content areas. When students do not develop the ability to comprehend what they read, they lose out on learning content in many other subject areas (Hall et al., 2000). For that reason, Gibson, Cartledge, and Keyes (2016) argued that reading proficiency is the most important skill for students to acquire. Additionally, Armbruster (2010) contended that failing to learn to read has a tremendous negative long-term impact on students' self-confidence and motivation to learn. In sum, if students do not acquire foundational reading skills in primary grades, they are unlikely to ever become proficient readers, will continue to struggle in later grades, and are more likely to drop out of school.

Literacy. The importance of developing reading skills is not only important to students inside of school, but also to their success outside of school. Two decades ago,

the Committee on the Prevention of Reading Difficulties in Young Children (Committee on Prevention) (1998) stated that "to be employable in the modern economy, high school graduates need to be more than merely literate. They must be able to read challenging material, to perform sophisticated calculations, and to solve problems independently" (p.20). This problem is not new. In the early 1970s, the Right to Read Office reported that a significant percentage of adults lacked "survival literacy" meaning that they experienced difficulty reading job-related instructional manuals and filling out application forms for employment, driver's licenses and completing other functional tasks (Chall, 1983).

The Committee on the Prevention of Reading Difficulties in Young Children (1998) attributed such low literacy rates to the rising demands of what it means to be literate. An increasingly technological society continually demands higher levels of literacy with increasingly serious consequences for those who cannot meet these demands (p. 1). This demand for higher levels of literacy is underscored by states' adoption of the Common Core State Standards which significantly raised the requirements for reading proficiency and "increase[ed] the challenge for students who are at risk for reading failure" (Bennett, Gardner, Cartledge, Ramnath, & Council, 2017, p. 146).

Given the consequences of not achieving proficient levels of reading in early elementary school, it is not surprising that improving children's reading proficiency continues to be a focus of both federal and state legislation, including the No Child Left Behind Act, the Every Student Succeeds Act, and state legislation requiring reading intervention for struggling students. Idaho House Bill 526, which went into effect on July 1, 2016, required school districts to implement literacy intervention programs that

provide “proven effective research-based substantial intervention includ[ing] phonemic awareness, decoding intervention, vocabulary, comprehension and fluency . . . based on a formative assessment designed to . . . identify such weaknesses” (Idaho Legislature, 2016). This legislative mandate presented significant challenges for districts to implement in a matter of only a few weeks when school resumed. The simple answer for many districts was to adopt a software platform that would meet the requirements of the statute.

To that end, the Washington School District adopted Lexia Core5 [Core5 or Lexia] as its primary intervention for at-risk readers in elementary school. Lexia Core5 is a computer-adaptive instructional program (CAI) designed to “provide explicit, systematic, personalized learning in the six areas of reading instruction” (“Lexia Reading Core5,” 2015, sec. Lexia Reading Core5). According to the Lexia Learning website, Core5 is designed to support student learning by providing adaptive and scaffolded instruction using embedded assessment to provide teachers “real-time, norm-referenced and criterion-referenced data” on student’s reading progress (“Lexia Reading Core5,” 2015, sec. Core5’s Personalized Learning Model).

Instructional Design. The Core5 teacher’s manual asserts the program’s alignment to “rigorous reading standards, including the Common Core State Standards” and proprietary “Assessment without Testing” technology that gathers student performance data as key components of its effectiveness (Lexia Learning Systems, LLC, 2017, p. 4). The Lexia program provides direct and scaffolded instruction in the foundational reading skills identified by the National Reading Panel organized into the following strands: (a) phonological awareness, (b) phonics, (c) structural analysis, (d)

automaticity and fluency, (3) vocabulary, and (f) reading comprehension (Schechter, Macaruso, Kazakoff, & Brooke, 2015). The total program is comprised of 18 levels of instruction, which are in turn comprised of 5 activities consisting of 6-20 units in each activity. Units address specific sub-skills in each main reading skill and increase in difficulty and complexity as students progress through each activity (Lexia Learning Systems, LLC, 2017). At Level 1, activities begin with rhyming units to teach phonological awareness, upper and lower-case letter units to teach phonics, and listening and picture activities to teach comprehension skills.

Phonological awareness. Core5 targets phonological awareness skills through sequential levels of activities that begin with recognizing rhyming words and blending syllables in spoken words. Students then receive instruction in analyzing and synthesizing individual phonemes that have the same beginning and ending phonemes as well as blending and segmenting individual phonemes, both of which are foundational early literacy skills (Bursuck & Damer, 2015). Words increase in complexity at the higher levels of instruction (Lexia Learning Systems, LLC, 2016d).

Phonics. Core5 phonics instruction begins with students first identifying graphemes (letters) and then progressing to knowledge in the relationship of sounds to letters for consonants and vowels in pictured words. Phonemic awareness is reinforced through "the analysis of initial and final consonants as well as medial vowels." Through these activities, students develop understanding of “syllable types, syllable division and simple spelling rules that are based on letter-sound correspondences as they build their decoding skills” (Lexia Learning Systems, LLC, 2016c, para. 3). Activities progress sequentially to recognition of more complex sound and syllable patterns and applying

word attack strategies to decode phrases and sentences (Lexia Learning Systems, LLC, 2016c).

Fluency. Lexia Core5 systematically integrates fluency instruction into activities that "address critical elements of fluency related to phrasal chunking and prosody" (Lexia Learning Systems, LLC, 2016a, pt. "Vocabulary"). At the upper levels of instruction, fluency is developed through timed silent reading of multi-paragraph passages of both narrative and informational text with integrated MAZE activities (see Figure 2 below. Fluency instruction is designed to increase processing speed while maintaining a focus on reading comprehension. The Lexia Skill Builders® and Lexia Lessons® support materials provide additional non-CAI instruction to develop expression and appropriate prosody (Lexia Learning Systems, LLC, 2016f).

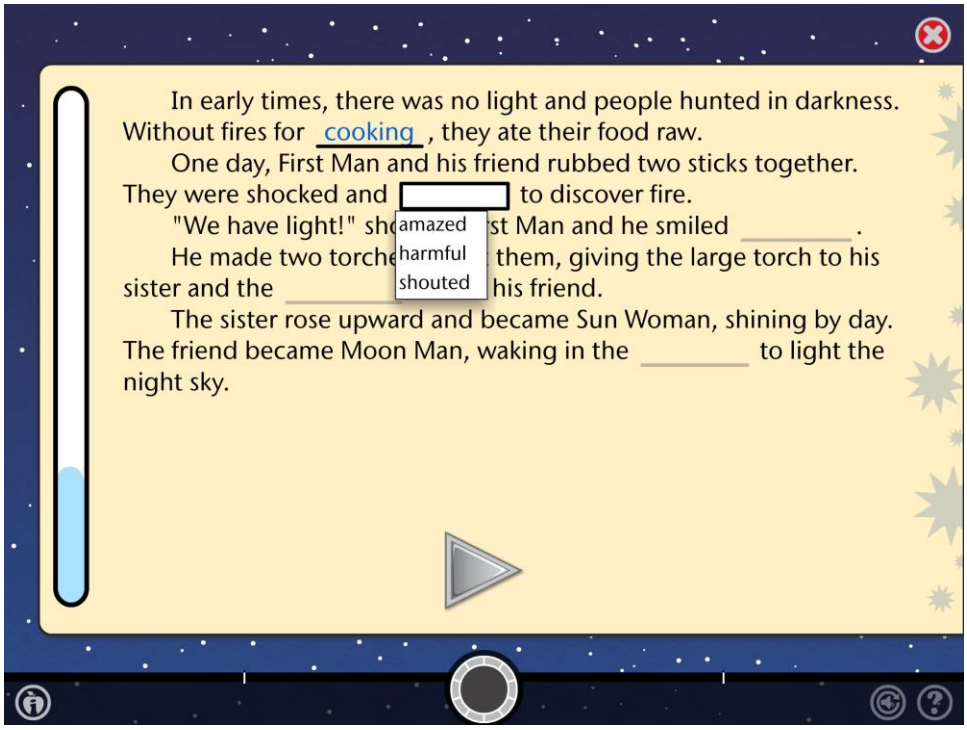

Figure 2. Screenshot of Lexia Core5® Fluency Passage with MAZE Activity

From *Lexia Core5*® software program, Lexia Learning, 2018. Reprinted with permission.

Vocabulary. Vocabulary instruction in Lexia helps students gain strategies to decode and learn new words and "to provide exposure to rich and varied vocabulary words . . . and to develop an awareness of word relationships and associations" (Lexia Learning Systems, LLC, 2016f, para. 3). Key to the instructional design are activities designed to help "students to think critically about words and their meanings and to apply strategies to build their own vocabulary for unfamiliar words and concepts" (Lexia Learning Systems, LLC, 2016f, para. 3). The lowest levels of instruction begin with developing oral vocabulary by associating word meanings with pictures. Instruction progresses to using context clues to decode words and culminates in recognizing logical relationships between words through analogies and nuances in different forms of words (Lexia Learning Systems, LLC, 2016f).

Structural analysis. Lexia provides further vocabulary development through activities that help students learn to analyze the structure of words by identifying both the syllables and morpheme structure of words. Pre-K instruction begins with using word attack strategies to decode words. Students then learn to identify meaningful word parts, including prefixes, roots and suffixes that make up multi-syllabic words as shown in Figure 3. Students progress from recognizing simple prefixes and suffixes to learning Latin suffixes and spelling rules based on the morphological structure of words, and finally, Greek forms that teach them to read and comprehend vocabulary in the science and arts (Lexia Learning Systems, LLC, 2016e).

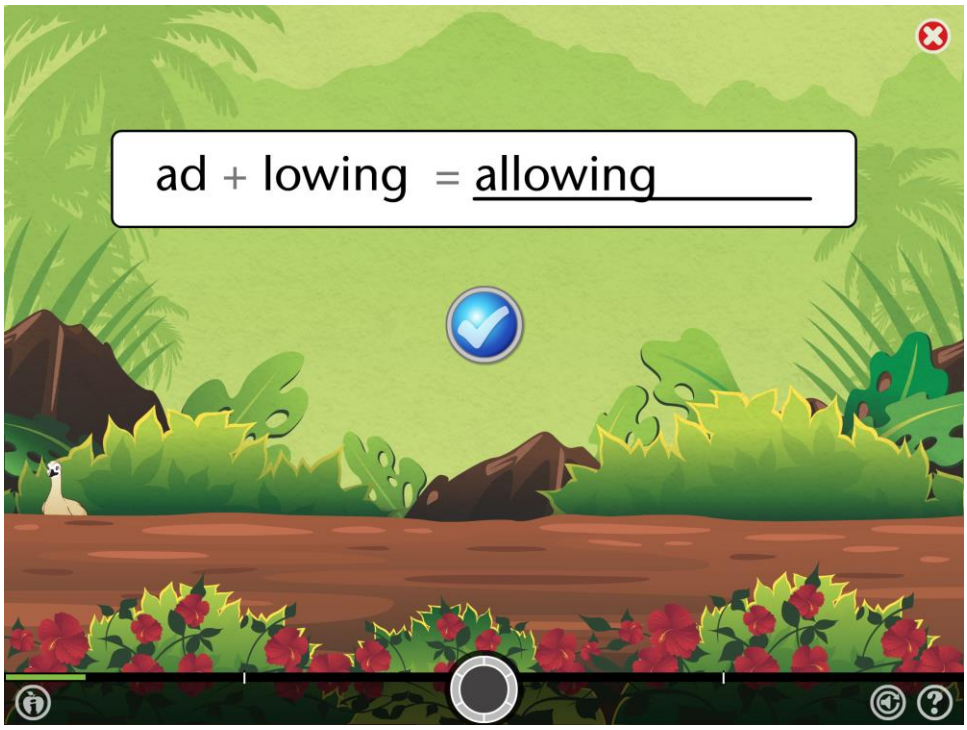

Figure 3. Screenshot of Lexia Core5® Structural Analysis Activity with Prefixes.

From *Lexia Core5*® software program, Lexia Learning, 2018. Reprinted with permission.

Reading comprehension. Lexia develops active reading skills by "having students engage with information they hear and read and by teaching them to think critically about this information" (Lexia Learning Systems, LLC, 2016b, para. 5). At Level 1, Pre-K comprehension activities build language comprehension skills through listening activities where students listen to stories and analyze the sequence of events and details of the story, providing a foundation for deeper comprehension activities. At Levels 17 and 18, fifth-grade instruction includes reading passages that are several paragraphs long and include both narrative and informational texts. Questions focus on eliciting higher order responses, including making inferences, drawing conclusions, analyzing cause and effect, comparing and contrasting, differentiating between facts and opinion, and identifying the

author's perspective. Figure 4 below is an example of a higher-order question from Lexia (Lexia Learning Systems, LLC, 2017).

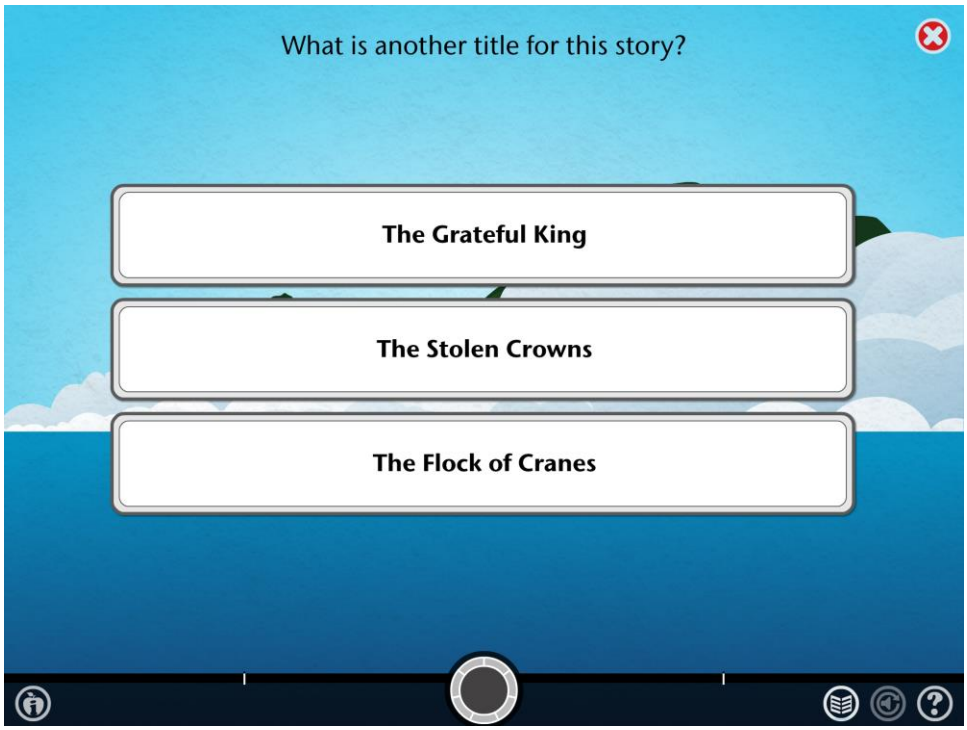

Figure 4. Screenshot of Lexia Core5® Text Comprehension Passage with Embedded Vocabulary Instruction.

From *Lexia Core5*® software program, Lexia Learning, 2018. Reprinted with permission.

Adaptive instruction. Students are initially placed in the Lexia program according to their performance on word recognition and comprehension activities designated by their grade-level assignment in the program. Teachers also have the ability to manually change a student's placement in the program. Lexia then employs a three-step instructional branching methodology to provide adaptive instruction to students. In the Standard Step, students are provided grade-level instruction that they work on independently. Students must demonstrate proficiency with 90% accuracy in their responses before moving on to the next unit of instruction. In the Guided Practice step instruction is scaffolded by removing distractors, simplifying visual components,

adjusting the complexity of the text, or providing embedded support to students. In the Instruction Step, the teacher intervenes by teaching identified skills directly to students. This step is only provided when students struggle with a particular skill. If students branch to the instruction step more than once, they receive a flag in the program that informs the teacher to provide an explicit Lexia lesson to the student (Lexia Learning Systems, LLC, 2017).

The Lexia platform also provides teachers with key information on students' performance through the MyLexia.com website. Through this site, teachers can monitor students' performance and print achievement awards for students, as well as additional supporting print-based instructional and intervention activities. The platform also provides teachers with additional instructional strategies and routines for individual, small-group, or whole class instruction (Lexia Learning Systems, LLC, 2017). These features appear to be highly aligned with research findings on effective Computer Adaptive Instruction (CAI) instructional design.

Statement of the Problem

Addressing the high percentage of students who do not learn to read proficiently before fourth-grade continues to be a focal point of national, state, and local education policies and plans. Similar to legislation in other states, Idaho adopted legislation in 2016 that required local school districts to establish literacy intervention programs for students who do not demonstrate reading proficiency benchmark on the state early reading assessment. Reading intervention programs are required to include "proven effective research based substantial intervention" that provides intensive development in phonemic awareness, phonics, fluency, vocabulary, text comprehension, and decoding.

Interventions must be targeted to address specific weaknesses in students' reading development based on formative assessment (Idaho Legislature, 2016). Teachers are also required to "monitor the reading progress of each student's reading skills throughout the school year and adjust instruction according to student needs" (Idaho Legislature, 2016, p. 509). Providing this intensive reading intervention program in addition to the regular core instruction presents a challenge for classroom teachers, especially in light of the recent adoption of the Common Core State Standards that require more time intensive instruction for all students (Bennett et al., 2017).

In response to this statutory mandate, a number of school districts in Idaho implemented online or digital reading intervention programs which are specifically allowed by the statute. Such online interventions are classified in the research literature as computer-assisted instruction (CAI), computer-adaptive instruction (CAI), or sometimes integrated-learning systems (ILS). Potential benefits of CAI include embedded formative assessment, individually paced instruction, extensive opportunities for repeated practice, and immediate feedback to students (Fenty, Mulcahy, & Washburn, 2015; Keyes et al., 2016).

As the use of CAI to support classroom instruction continues to increase, it is critical to understand whether it provides a valid alternative to teacher-led instruction (Fenty et al., 2015). While publishers of programs often provide research supporting the effectiveness of their programs, districts have a moral imperative to understand whether the interventions they provide to students actually deliver the intended results; otherwise, districts will continue to spend hundreds of thousands of dollars without actually improving learning outcomes. Further, in larger school districts where CAI programs are

deployed across a number of different schools and classrooms, identifying whether certain teachers achieve significantly higher results allows districts to identify and share effective practices with other teachers in the district to ensure high levels of learning for all students.

Purpose of the Study

The primary purpose of this study was to identify the impact of participation in the Lexia Core5 reading intervention program on gains in reading achievement for second-grade students. A secondary purpose was to identify the impact of potential key factors including hours of student participation, number of completed levels, assigned classroom teacher, program level of implementation, teacher years of experience, class size and student at-risk factors. The tertiary purpose for the study was to identify any shared practices or beliefs of teachers who students achieved exceptional gains in reading.

Research Questions

The following research questions were addressed in this study with the corresponding null hypotheses.

R1. Did student participation in the Lexia Core5 reading intervention program have a significant effect on growth in reading achievement?

H_10. Participation in the Lexia Core5 reading intervention program did not have a significant effect on growth in reading achievement.

R2. What key factors may have influenced the effect of Lexia Core5 program on student achievement?

H_2O. No key factors will have a significant influence on the effect of Lexia Core5 on student achievement.

R3. Do teachers with high effect sizes on student reading gains share common perceptions, beliefs, or practices that may explain the effect of Lexia Core5 on student achievement?

Significance of the Study

The impact of using technology to improve student learning outcomes has been debated in the literature for decades. One of the most significant and well-known arguments came from Clark and Kozma in the 1980s and 1990s. In 1983, Dr. Richard Clark criticized the influence of the multimillion dollar education technology industry in proselytizing the belief that media influence learning, which he argued was an unfounded myth. In his extensive meta-analysis of media comparison studies, Clark (1983) found "strong evidence that media comparison studies that find causal connections between media and achievement are confounded" (p. 447). Clark's (1983) argument was simple and pointed: media are nothing more than "delivery vehicles for instruction and do not directly influence learning" (p. 453).

Economic Impact

Clark's primary contention was that the instructional method is the only variable that influences learning; therefore, if media are reduced to their core instructional strategies, replicating the embedded instructional strategies in another media will produce the same effects. Clark (1994) argued that media's influence, therefore, is only economic: "media and their attributes have important influences on the cost or speed of learning but only the use of adequate instructional methods will influence learning" (p. 27). This

actually provides a compelling argument to find the most efficient method of delivering instruction to students. Clark's stance seems to be somewhat nonchalant about the potential efficiencies of technology, as though time is somehow irrelevant in the learning process. While that may be true in a theoretical examination of learning results, it does not apply as a practical matter in classrooms where learning is constrained by daily, weekly, and yearly schedules. For primary grade teachers who instruct students with wide-ranging levels of reading ability, providing individualized and paced instruction that meets students' unique needs may not be possible in their limited amount of instructional time (NRP, 2000a). It simply may not be possible for a teacher to deliver the same levels of formative assessment, feedback, and individualized instruction that computerized programs can deliver in the same time frame.

Instructional Design

Similarly, Clark (1983) posited an alternative hypothesis to the instructional time saved from using computers, attributing the difference in effort by students on computers to "presumably . . . more instructional design and development [resulting] in more effective instructional methods for the students in computer treatments" (p. 449). This argument also speaks to the rationale for schools to invest in computer-assisted instruction. Arguably, education technology providers, with a market of almost 100,000 schools in the United States alone, can provide a higher investment in the instructional design and development of their instructional models than a typical teacher can. This model for educational software is similar to the model schools have employed for decades in purchasing textbooks from subject-matter experts rather than expecting teachers to write their own curriculum.

Instructional Strategies

The overarching argument of Clark's media comparison research is that instructional strategies are the fundamental independent variable of learning: if any instructional media or technology is reduced to its core instructional strategies, those strategies can be delivered through a variety of media to achieve the same learning results. However, there is evidence to show that technology can enhance instructional strategies to increase their efficacy for students. One key example is the use of embedded formative assessment to provide individualized instruction for students, long recognized as one of the most effective strategies for improving student learning (Black & Wiliam, 2010; Brown, Hinze, & Pellegrino, 2008; Stiggins, 2004; William, 2010). Even though most teachers today accept the efficacy of formative assessment, it has yet to become widely adopted into regular classroom instruction (Stiggins, 2002). Advancements in technology, however, may hold the key to unlocking the potential and promise of formative assessment. One key element of formative assessment is the collection and reporting of learning results to enable teachers to adapt their instruction to individual needs. Computer assisted instructional systems can embed formative assessment into instructional delivery to not only collect and report learning results, but to also respond dynamically to correct and incorrect responses. Pellegrino and Quellmalz (2010) argued that using technology to build on cognitive theory has led to adaptive testing that includes built-in accommodations, scaffolding, and immediate feedback, the keystone elements of computer assisted instruction (p. 120). Extending the concept of formative assessment, Shute and Kim (2014) proposed the concept of "stealth assessments" which they defined as evidence-based assessments that are embedded into "highly interactive and

immersive" learning activities such as computer-based instructional systems or games (p. 315). Without disrupting the learning process, stealth assessments invisibly collect student learning results and provide teachers with immediate feedback on students' progress on learning goals, enabling teachers to make more timely instructional decisions.

Both Media and Methods May Influence Learning

Other theorists, however, have argued against the conclusions that Clark drew from his meta-analysis. Kozma argued that media and methods have a reciprocal relationship where each influences learning as well as each other. Kozma (1994) contended that "traditional models of instructional design do not address the complex interrelationships among media, method, and situation. In general, they are not compatible with constructivist, social models of learning, being as they are derived from behavioral models" (p. 17). Constructivist learning theory was central to Kozma's (1994) argument as he contended that rather than being a passive response to a delivery of instruction, learning occurs by strategically employing "cognitive, physical, and social resources to create new knowledge by interacting with information in the environment"; therefore, media should be designed to interact and influence these processes of learning (p. 8). Kozma (1994) argued that rather than "an unnecessary and undesirable schism" between methods and medium, the two must have an integral relationship for effective instructional design (p. 16). When media and method are integrated effectively and designed into the complex social and cultural environments of learning, media makes a significant contribution to learning. Ross (1994) further contended that the stances of Kozma and Clark were not diametrically opposing views, but instead, "not a debate at all,

but . . . two sets of arguments on two different questions" (p. 5). Ross further argued that learning is a complex process that defies a universally accepted definition and the competing theories of behaviorism and constructivism have a strong influence on researchers' views of how to evaluate the influence of technology on learning (Ross, 1994). More recently, Cheung and Slavin (2011) argued that "the Clark–Kozma debate has been overtaken by the extraordinary developments in technology applications in education in recent years. It may be theoretically interesting to ask whether the impact of technology itself can be separated from the impact of particular applications, but as a practical matter, machine and method are intertwined" (p. 199).

As researchers have continued to investigate the impact of technology on learning, results have been less than conclusive. Meta-analyses have typically shown that use of education technology has a small to moderate effect on reading achievement (Cheung & Slavin, 2011). Such large-scale approaches to analyzing the impact of technology provide insight into its effectiveness; however, the vast array of hardware and software that comprise the universe of education technology limits their insight into the effect of specific applications. It may be much more insightful to evaluate the impact of specific applications which have been designed to achieve specific outcomes. Further, there is often significant variation in how such applications are implemented in the classroom. Because certain teachers may elicit higher outcomes for students based on their level of engagement with and fidelity to the protocols of the program, only evaluating the overall impact of a CAI application may not sufficiently explain its effect.

This investigation into the effect of Lexia Core5 on early reading gains primarily informed the Washington School District whether the program has provided its intended

learning outcomes. Further, it may also inform other districts both within Idaho and in other states on the efficacy of the Lexia Core5 program. Finally, it may serve to inform policymakers in Idaho of the practicality of mandating intervention programs that may or may not be effective in increasing students' reading achievement.

Research Design

The mixed methods research design employed an explanatory-sequential design. Johnson, Onwuegbuzie, and Turner (2007) defined mixed methods as research which "combines elements of qualitative and quantitative research approaches . . . for breadth and depth of understanding and corroboration" (p. 123). Creswell and Plano Clark (2018) noted that combining "quantitative and qualitative data provides a more complete understanding of the research problem than either approach by itself" and posited that this approach may be the most effective for program evaluation (p. 8). This research study addressed two key questions. The first question was whether or not the Lexia Core5 program achieved a positive effect on student reading gains, which necessitated a quantitative approach. The second key question was how certain teachers may have been able to achieve higher than expected outcomes. This question was addressed through qualitative research, specifically interviews with purposefully sampled teachers. Qualitative findings were not only used to help explain the quantitative results, but to also inform the direction on how to expand the identified beliefs and practices throughout the district to attain similar results for all students.

In the first phase, a quantitative analysis compared the mean percentile gain of current second-grade students who have participated in the Lexia program with the mean percentile gain of prior years' second-grade students who did not participate in the

intervention program. An independent t-test was used to evaluate the outcomes of the post-test for the two groups. The quantitative phase also addressed the second research question through multiple regression and ANOVA analyses to identify the influence of key factors on the impact of Lexia Core5. This step included identifying key factors at the program, classroom, student and teacher levels including level of program implementation. In the qualitative phase, second-grade teachers were purposefully sampled using the extreme case strategy to identify common perceptions among teachers with exceptional reading gains of the efficacy, benefits, and challenges of implementing the Lexia Core5 intervention program.

Definition of Terms

The following definitions were used for the purpose of this study.

Reading Comprehension. The construction of the meaning of a written text through a reciprocal interchange of ideas between the reader and the message in a particular text (NRP, 2000a).

Fluency. The ability to read text accurately, rapidly and efficiently (NRP, 2000a).

Graphemes. Character representations of phonemes in written language. Graphemes may consist of one letter or multiple letters. For example, both f and ph represent the phoneme /f/ in English (NRP, 2000a).

Phonemes. The smallest units that compose spoken language and are combined in to create syllables and spoken words. Phonemes are depicted in slashes, i.e. /ch/ (NRP, 2000a).

Phonemic awareness. The ability to recognize and manipulate phonemes by blending spoken sounds or segmenting spoken words into individual sounds (NRP, 2000a).

Scaled Scores. Scaled scores are the fundamental scores used to summarize students' performance on Star Reading tests. Upon completion of Star Reading, each student receives a single-valued Scaled Score. The Scaled Score is a non-linear, monotonic transformation of the Rasch ability estimate resulting from the adaptive test. Star Reading scaled scores range from 0 to 1400. This scale is a "vertical", or developmental, scale used to summarize the progression of students from Kindergarten through grade 12 performance levels (Renaissance Learning, 2017).

CHAPTER TWO: REVIEW OF THE LITERATURE

This chapter provides a review of the relevant literature on the research problem. This section will provide the theoretical perspective for learning to read as well as the theoretical basis for computer assisted instruction. Following the theoretical perspective, the review of the literature will include research on the effect of computer assisted instruction on reading achievement and studies researching the effectiveness of the Lexia Core5 program. The methods for the literature review included searching databases for the key topic of Lexia Core5 and Lexia Reading. From these publications, the researcher identified key meta-analyses that have synthesized research on computer assisted instruction and the impact of CAI on learning to read as well as other recent articles on other CAI interventions for reading.

Theoretical Perspective

This section will describe the theoretical perspective on how Lexia Core5 may influence reading achievement of second-grade students. This perspective is framed by the following constructs: (a) prevailing theories of how students learn to read, (b) the essential elements of reading instruction, (c) the rationale for providing more intensive intervention for students who are at-risk of not learning to read, and (d) the basis for computer-assisted instruction including key beliefs of behaviorist learning theory.

How do students learn to read?

Adams' Processor Theory. In her comprehensive and foundational work, *Beginning to Read*, Marilyn Adams (1990) drew on an extensive review of research from

the fields of psychology, education, linguistics, anthropology, and computer science to describe how children develop the ability to read. Adams described fluent and meaningful reading as a system of four independent processors working interdependently. The system is comprised of an orthographic processor that perceives written letters (graphemes) and their sequence, the phonological processor that translates letters into their spoken sounds (phonemes), the meaning processor that contains vocabulary knowledge, and the context processor that constructs understanding of the text (Adams, 1990; Adams, Stahl, Osborn, & Lehr, 1990). When students read fluently, they are unaware of how their brains coordinate disparate information from these four processors. Bursuck and Damer (2015) noted that students who struggle to learn to read experience problems in at least one, if not more, of these processing domains. These students require effective interventions beyond core instruction to develop their specific areas of difficulty. For example, some students may have adequate vocabulary knowledge to understand the meaning of words but may not have sufficient ability to decode text accurately or to read fluently enough to understand the text.

Essential Elements of Core Reading Instruction**.** Core instruction refers to the regular classroom instruction that every child receives at each grade level. To prevent comprehension difficulties in later grades, in the earliest grades all children—and especially at-risk children—should receive core instruction that promotes language and literacy growth and that actively builds linguistic knowledge and comprehension (Committee on the Prevention of Reading Difficulties in Young Children, 1998). Current beliefs about core instruction to develop reading skills trace their foundation to Jean Chall's seminal text, *Learning to Read: The Great Debate* (1967) which synthesized then

current research on reading instruction. Three decades later, Congress convened the National Reading Panel to facilitate effective reading instruction by evaluating and synthesizing the current research-based knowledge on developing literacy (NRP, 2000a). The Panel identified five essential areas for reading instruction: (a) phonemic awareness, (b) phonics, (c) fluency, (d) vocabulary, and (e) text comprehension (Bursuck & Damer, 2015; Wood, Mustian, & Lo, 2013).

Providing Intervention for At-Risk Readers

The failure of many American children to achieve grade-level reading proficiency by fourth-grade continues to be a national concern. As the only national assessment of reading skills, the National Assessment of Education Progress (NAEP) is the most frequently cited statistic for American students' reading ability (Santoro & Bishop, 2010). According to the scores from the 2015 NAEP, 31% of fourth-grade students could not read at a basic level, indicating that they "were unable to locate relevant information, make simple inferences, use their understanding of the text to identify details that support a given interpretation or conclusion, [or] . . . interpret the meaning of a word as it is used in the text" (National Center for Education Statistics, 2016).

For many children, providing systematic, research-based core instruction is not sufficient to achieve grade-level reading proficiency. For these at-risk students, schools and teachers must provide additional instruction and support—known as intervention—to help them develop the necessary skills to become proficient readers (Gibson, Cartledge, & Keyes, 2011; Santoro & Bishop, 2010). Santoro and Bishop (2010) underscored the importance of providing intervention, stating that "one of the most compelling findings from reading research is that children who get off to a poor start in reading rarely catch

up" (p. 99). Cooper et al. (2017) argued that for struggling readers to make more than yearly growth in reading, they will need both core instruction and effective intervention strategies and resources aligned to the same standards. Therefore, efforts to increase reading achievement must focus on providing effective interventions for at-risk students as well as improving core reading instruction. The Committee on Prevention (1998) clarified that purpose of providing such interventions is "not simply to boost early literacy achievement," but also to help at-risk students "achieve levels of literacy that will enable them to be successful through their school careers and beyond" (p. 247).

Content of Effective Interventions. Wanzek & Vaughn (2007) noted that interventions differ from core reading instruction in that they are designed to address the specific instructional needs of those students who are at-risk for not developing adequate reading skills. The Prevention Committee (1998) identified three potential stumbling blocks to students becoming skilled readers: (a) "difficulty understanding and using the alphabetic principle," (b) "failure to transfer the comprehension skills of spoken language to reading," and (c) a lack of motivation to read or appreciation of the rewards of reading (p. 2). Effective intervention programs, therefore, must address phonological awareness, word decoding, and letter naming and sound knowledge (Mioduser, Tur-Kaspa, & Leitner, 2000; Santoro & Bishop, 2010).

Effective Delivery of Interventions. Effective interventions should be delivered with focused intensity as small-group, individual, or peer assisted instruction, "progress[ing] systematically from teacher directed to student-directed learning" with strategic cognitive supports (Santoro & Bishop, 2010, p. 100). Mioduser et al. (2000) further noted that research has shown that effective interventions in these areas not only

improve early reading skills, but also produce a long-range effect over several years as reported in longitudinal studies. Effective interventions include the following features: (a) highly structured and fast-paced instruction, (b) sequencing based on text complexity, (c) instruction that scaffolds from teacher modeling to student modeling to independent practice, (d) one-on-one tutoring or small-group instruction, (d) ongoing assessment and monitoring, and (g) instruction from a qualified and certified teacher (Cooper et al., 2017, p. 371). Torgesen, Meadows, & Howard (2006) also recommended that interventions must be research-based and may include technology resources as well as small group interventions.

At-Risk Populations. Certain populations of students have historically been at higher risk for failing to achieve reading proficiency including students with disabilities, students from low socio-economic homes (SES), racial minorities, and English Language Learners (ELL). The Committee on Prevention (1998) argued that ensuring success in reading necessitates providing different levels of intervention for at-risk segments of the population. Fälth, Gustafson, Tjus, Heimann, & Svensson (2013) further noted that at-risk students are not a homogeneous group so teachers and schools will need to provide different types of interventions to address their individual disabilities and challenges. For example, Bursuck and Damer (2015) stated that many children living in poverty "enter school with delayed development in all areas of language that prevent the efficient functioning of all four processors. These children require intensive instruction in vocabulary and language concepts as well as word reading and fluency" (p. 6).

Response to Intervention (RTI). To address the different needs of at-risk students, many schools have adopted the Response to Intervention (RTI) model of providing

systematic and tiered levels of supports to students, depicted in Figure 5 (Bursuck & Damer, 2015). Each level consists of research-based instruction that varies in intensity and/or duration based on student need (Wanzek & Vaughn, 2007). Tier 1 consists of delivering regular core reading instruction and making individual instructional decisions as necessary. For example, if a struggling reader lacks the appropriate vocabulary for a reading selection, the teacher would provide individual activities to help the student gain the necessary knowledge to understand the text. Tier 2 instruction is delivered to small-groups and focuses on developing specific skills to address deficiencies among the group. The purpose of Tier 2 intervention is to accelerate students' reading acquisition to enable them to catch up to their peers, often referred to as "closing the gap" (Bursuck & Damer, 2015). Tier 3 intervention is designed for struggling readers who have the most severe needs. Tier 3 interventions are the most intensive and focus on key foundation skills. Wanzek and Vaughn (2007) identified different ways to increase the intensity of interventions, including decreasing the size of small-group instruction, increasing the amount of time the intervention is provided to students, and providing students with more explicit instruction. Tier 3 intervention is explicit, highly systematic, and often provided on an individual basis (Bursuck & Damer, 2015; Cooper et al., 2017). In elementary school, classroom teachers typically work as grade-level teams to provide Tier 2 and Tier 3 intervention to students. Students with learning disabilities typically receive even more intensive interventions from a certified special education teacher as mandated in their Individual Education Plans (IEPs).

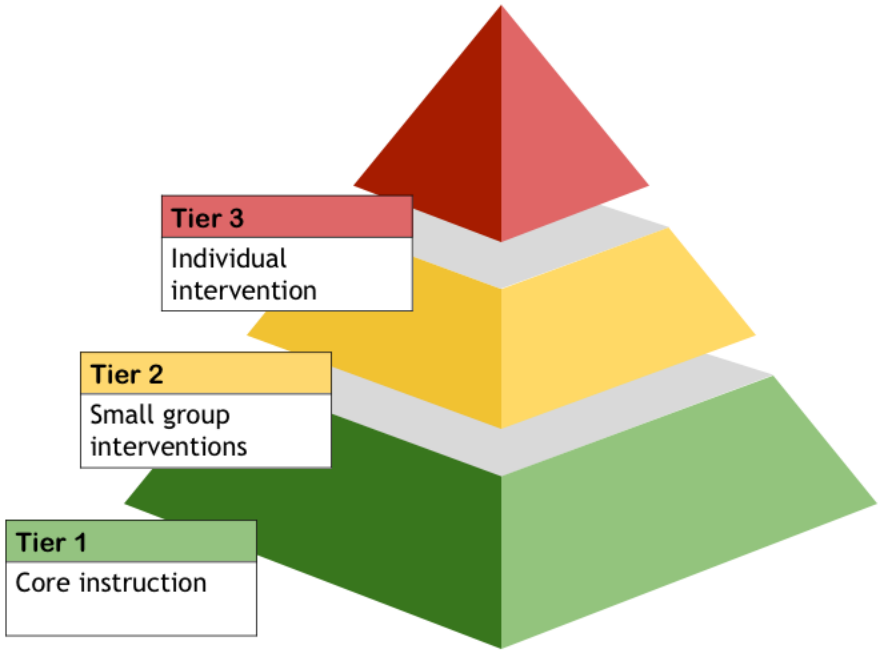

Figure 5. Response to Intervention (RTI) Three-Tier Model of Support

Delivery of Reading Intervention. While the RTI model has been widely implemented in schools across the United States, there is still debate about the most effective delivery method for interventions. Different theories of learning support different approaches: behaviorism undergirds a direct presentation method whereas constructivism undergirds an embedded or developmental model (Committee on the Prevention of Reading Difficulties in Young Children, 1998). These theories also influence whether interventions are delivered in a standardized or in an individualized way (Wanzek & Vaughn, 2007). Standardized interventions specify the elements of reading instruction that will be implemented based on outcomes from previous research. While teachers may make some individual adjustments to address individual students' needs, fidelity of implementation is fundamental to standardized interventions (Wanzek & Vaughn, 2007). Alternatively, interventions may be delivered in a more individualized approach by first defining the student's problems in behavioral terms, then setting

specific goals to address the problem, identifying an appropriate intervention to assist the student in meeting those goals, then monitoring the student's progress toward those goals, and finally adjusting the intervention as necessary and making instructional decisions about further interventions (Wanzek & Vaughn, 2007). Interestingly, in an extensive review of literature on reading interventions, Wanzek and Vaughn (2007) were unable to find any journal publications on interventions being implemented in an individualized approach. Advances in CAI over the past decade, however, may have made the individualized approach a reality in classroom interventions.

Effects of Providing Reading Intervention. A number of researchers have investigated the impact of providing interventions to at-risk students. In a synthesis of research on extensive interventions, Torgesen et al. (2001) found that reading interventions had a significant impact on students' reading achievement. The longer that students participated in an intervention, the more gains they made; however, the magnitude of the effect size was not dependent on the duration of the intervention. Similarly, Deno, Fuchs, Marston, and Jongho Shin (2001) found that students with learning disabilities achieved similar growth as their typical peers in reading fluency when they participated in effective reading intervention. Finally, Wanzek and Vaughn (2007) synthesized results from studies of extensive daily reading interventions provided for at least 20 weeks. Results were limited to experimental designs to provide the greatest evidence of the effect of the intervention. Included studies also measured results on standardized, norm-referenced assessments to allow the results to be generalized to general reading achievement rather than being limited to the specific skills targeted by the intervention. Their synthesis found positive outcomes for using extensive

interventions to increase achievement for at-risk students. Interventions that emphasized both phonics instruction and text reading had the highest impact. The results further suggested that interventions beginning in first grade were associated with higher effect sizes than those that began in second or third-grade.

Gale (2006) suggested that the importance of phonological awareness skills in reading development makes it a necessary target for early intervention. The Committee on Prevention (1998) cited experimental-design research showing that providing interventions in phonological awareness, including both explicit instruction and independent practice, resulted in both higher gains for participating students as well as decreased gaps with grade-level peers. While phonological intervention does affect the ability of students to decode words, this skill alone is not sufficient to ensure reading comprehension and other foundational skills must also be targeted for intervention (Committee on the Prevention of Reading Difficulties in Young Children, 1998; Saine, Lerkkanen, Ahonen, Tolvanen, & Lyytinen, 2011).

Computer Assisted Instruction and Intervention (CAI)

The National Reading Panel (2000b) stated that because students "vary greatly in the skills they bring to school . . . teachers should be able to assess the needs of the individual students and tailor instruction to meet specific needs" (p. 11). Providing intensive, systematic, and evidence-based intervention to small groups or individual students is a difficult challenge for schools and classroom teachers due to factors such as teacher shortages, budget constraints, and limited instructional time (Hall et al., 2000). These challenges may be more significant in urban schools that have limited funding and large class sizes (Mioduser, Tur-Kaspa, & Leitner, 2000). As a result, many school

districts have turned to education technology “to find quick and efficient solutions to perceived problems in reading achievement, and often, the focus is on improving early reading skills (Hall et al., 2000; Paterson, Henry, O’quin, Ceprano, & Blue, 2003). As early as 1992, one of every four school districts had used federal funding to install integrated learning systems (ILS) to improve student learning outcomes (Paterson et al., 2003). In 2002, the No Child Left Behind Act proposed up to five billion dollars to improve reading achievement, and many schools invested that funding for computer adaptive instructional programs (Tillman, 2010).

Even before computers became common in schools, researchers were designing software programs as reading interventions (Bennett et al., 2017). As early as 2000, Mioduser, Tur-Kaspa, and Leitner (2000) found that early reading training programs used advanced computer technology to support the needs of students with reading disabilities including digitized speech to enable association between graphemes and phonemes, touch-screens, advanced algorithms to provide individualized adaptive branching and sequence of instruction, pacing, and feedback to increase motivation and develop self-confidence. Today, most teachers use computers to supplement instruction in their classrooms (Shannon, Styers, Wilkerson, & Peery, 2015). The planned integration of computer technology into instruction to support learning is the basis of computer-assisted instruction (CAI) (Lovell & Phillips, 2009). CAI can provide students the opportunity to learn and practice skills without one-on-one attention from the teacher. This flexibility may enable teachers to overcome the challenges of providing Tier 2 and Tier 3 levels of intervention for struggling students (Bennett et al., 2017; Gibson et al., 2011).

The most recent report of American teachers' use of technology by the National Center for Education Statistics showed that the most common use of technology by students was to learn or practice basic skills. In elementary schools, 76% of teachers reported frequent use of technology for this purpose, 12% more than the next highest category, conducting research (Gray, Thomas, & Lewis, 2010). Interestingly, while students in schools with highest poverty rates had the lowest number of computers available to them, they had the highest frequency of use for learning and practicing basic skills as shown in Table 1 below.

Table 1 Number of Students per Computer and Use for Basic Skills by FRL Rate

School FRL Rate	Computers per 20 students	Frequent use to learn or practice basic skills
Less than 35 percent	13.4	61%
35 to 49 percent	11.8	63%
50 to 74 percent	11.2	73%
75 percent or more	11.2	83%

Note. Data from *Teachers' Use of Educational Technology in U.S. Public Schools: 2009. First Look*. NCES 2010-040. by L. Gray, N. Thomas, and L. Lewis, 2010. National Center for Education Statistics. Used with permission.

Given the gap in access to technology between the lowest and highest poverty schools and the primary ways that computers are being used in schools, it is important to understand the benefits of using computers to learn and practice basic skills. There is a convergence in education technology research on the importance of key instructional design features for Computer Adaptive Instruction that may provide advantages over traditional classroom instruction (Fälth et al., 2013; Hall et al., 2000; Lovell & Phillips,

2009; Santoro & Bishop, 2010). Santoro and Bishop (2010) found that "well-designed instructional software includes many of the critical features found to be effective for students with reading difficulties [including] explicit immediate feedback, extensive skills review, and consistent error correction procedures" (p. 100).

Definition of Computer Assisted Instruction (CAI).

Lovell and Phillips (2009) defined computer-assisted instruction (CAI) as the planned integration of computers into instruction to support student learning. CAI generally consists of drill-and-practice, simulations, instructional computer games, and tutorials. CAI may present new material or provide review of previously learned material. CAI can be used independently by students or as a support or extension of traditional instructional methods (Tillman, 2010). Santoro and Bishop (2010) held that computer technology should only be classified as computer-assisted instruction if it includes clear learning goals, appropriate instructional strategies, and content that includes embedded assessment and feedback. Bennett et al. (2017) noted that with the array of devices available to students today including smartphones and tablets, supplemental CAI is an integral part of American students' education.

Integrated Learning Systems. Cassady and Smith (2005) distinguished between computer-assisted instruction (CAI) and integrated learning systems (ILS) by describing CAI as "the traditional ancillary computer program that has limited materials and resources used for stand-alone enrichment or remediation" (p. 362). In contrast, they described ILS as being "aligned with curricula and used in concert with the instructional planning process" (p. 362). Putman (2017) also made the distinction that ILS is an "adaptive sequence systems that adjust instruction based on individual differences in

students' learning. . . and based on the concept of mastery learning" (p. 1154). As students master skills or content in the software, they progress successively through additional levels; if students fail to master skills, they are presented with remedial content until they can demonstrate mastery at their current level of understanding. However, this distinction is not widely recognized in the literature where the term computer-assisted instruction is used most frequently to describe software that supports instruction, either independently or in conjunction with traditional instruction, including those systems that Cassady and Smith and Putman identified as ILS. A Google Scholar keyword search of academic journal articles published in the last five years where each of these terms was combined with reading found 20 times as many articles published for the term "computer assisted instruction" compared to "integrated learning system."

Soe, Koki, and Chang (2000) identified three levels of computer-assisted instruction: (a) drill-and-practice, (b) tutorial, and (c) dialogue. Drill-and-practice applications provide students with independent practice to learn skills they have already learned in the classroom. The computer provides individual and immediate feedback to students. Tutorial applications provide direct instruction to students in addition to immediate practice. The content of the instruction as well as the pacing is often individualized to the student based on results from embedded assessment. Dialogue applications provide the opportunity for students to take an active role in their learning by providing instructions to the computer to structure their own learning.

Behaviorist Theoretical Basis for CAI

As early as 1901, John Dewey postulated that effective instruction must be based on theory rather than arbitrary individual judgments (1901). Schunk (2012) defined

theory as “a scientifically acceptable set of principles offered to explain a phenomenon, theories provide frameworks for interpreting environmental observations and serve as bridges between research and education” (p. 10).

While designing theoretically sound and empirically valid instructional systems presents a difficult and challenging task (Lee & Park, 2008), the instructional design of most CAI systems reflects both behaviorist and constructivist theoretical underpinnings. Often, behaviorism and constructivism are viewed as two competing and incompatible theories; however, Schunk (2012) stated that “it is not necessary to completely reject behavior theories in favor of cognitive ones. . . behavior principles can be applied without wholly subscribing to conditioning theories” (p. 101). In fact, neither theory appears to sufficiently explain all of the complexities of learning. As a result, instruction in American classrooms today typically reflects influences from both behaviorism and constructivism. This is true of computer-assisted instruction as well. Keyes et al. (2016), for example, cited the following instructional design elements of CAI: active engagement and interaction (constructivism), immediate and corrective feedback (behaviorism), reinforcement (behaviorism), modeling (constructivism), individual pacing (behaviorism), interesting and motivating activities (constructivism), repeated practice of skills (behaviorism), learning in non-threatening or embarrassing environments (constructivism) (p. 143). Tenets of constructivism often found in computer-adaptive instruction include recognizing stages of learner development, targeting students’ zones of proximal development, and instructional scaffolding (Putman, 2017). Tenets of behaviorism commonly found in CAI include providing rewards as positive reinforcers,

segmenting and sequencing instruction into smaller steps, and providing effective and timely feedback.

Putman (2017) described the two theoretical approaches as the difference between learning from a computer or learning with a computer. Learning from a computer reflects the tenets of behaviorism with the computer primarily providing reinforcement and feedback, while learning with a computer reflects the tenets of constructivism and "acknowledges the broader cognitive and social components of learning using technology . . . as well as the multiple realities of combining technology and learning" (p. 1156). Similarly, Cassady and Smith (2005) contended that computers are integrated into instruction with the expectation that students will use them to learn either through supportive practice and skill instruction (behaviorism) or "by promoting a constructivist classroom context in which learners are able to have their individual growth and learning supported" (p. 362). Interestingly, however, the ideals of individual growth and learning were held as ideals of behaviorism before they were ascribed to constructivism.

Based on the theories of Thorndike, Pavlov, Guthrie and Skinner, behaviorism explains learning in terms of associations between stimuli and responses (Schunk, 2012). Skinner posited an operational conditional model involving a discriminant stimulus, response, and reinforcing stimulus (Skinner, 1968). Behavior changes as a result of consequences: reinforcing consequences increase behavior while punishing consequences decrease behavior. Complex behaviors are formed by continually reinforcing successive iterations of the desired behavior.

Putman (2017) stated that most CAI applications are based on the assumptions of behaviorism including providing repetition, immediate feedback, and reinforcement.

Slavin's QAIT model for evaluating the effectiveness of various CAI applications also reflects the tenets of behaviorism. This model posits that effective teaching is the product of the following factors: (a) quality of instruction, (b) appropriate levels of instruction, (c) extrinsic and intrinsic motivation—incentives, and (d) providing sufficient instructional time (Cheung & Slavin, 2012). Santoro and Bishop (2010) argued that these critical elements of instructional design support students with reading difficulties and cited empirical evidence of the effectiveness of CAI as a reading intervention. Lovell and Phillips (2009) argued that the effectiveness of technology use in the classroom depends on evaluative and feedback components that allow the program to monitor students' progress and adapt instruction to students' individual education. As early as the 1950s and 1960s, Skinner described the potential impact of teaching machines that could provide individualized pacing and feedback to students (1968). Predating classroom computers, these machines were based on a prototype developed by Pressey in the 1920s. The devices responded dynamically to students' correct and incorrect responses. Skinner (1968) posited that the use of these machines would allow students to learn content at their own individual pace. The machines that Skinner developed went beyond the original design to include open-ended responses from students and carefully designed sequential instruction.

Systematic Teaching. Systematic teaching is one foundational tenet of behaviorist theory. Bursuck and Damer (2015) defined systematic instruction as "teaching that clearly identifies a carefully selected and useful set of skills and then organizes those skills into a logical sequence of instruction" (p. 15). Skinner (1968) stated succinctly, "Material which is well organized is also, of course, easier to learn" (p. 107). In his

description of teaching machines, Skinner (1968) advocated for instruction designed as sequential small steps that the learner completes in a prescribed order. Fenty, Mulcahy, and Washburn (2015) noted that computer-assisted instruction provides student support with "targeted, systematic, and explicit reading instruction" that may provide more intensive support and direct practice for students than teacher-led interventions which most often occur in small groups, forcing students to take turns and limiting their opportunity for practice (p. 141). CAI may therefore "provide students with increased opportunities to interact with text in meaningful ways" (Fenty et al., 2015, p. 142).

Feedback. Behaviorist theory emphasizes the importance of feedback in shaping learning. However, given the number of students assigned to their classrooms, teachers may not be able to provide reinforcement as frequently or at the most appropriate time for it to be effective. Schunk (2012) noted that because teachers can only attend to students individually for a few minutes each day, students do not receive feedback in time to avoid learning incorrectly. Through CAI, students can interactively engage in instruction and receive immediate and corrective feedback, as well as reinforcement and modeling (Keyes et al., 2016; Macaruso & Rodman, 2011a).

Adaptive Instruction. Computers can not only provide feedback immediately, they can also dynamically change the instructional activities that students receive based on their level of performance. Adaptive instruction refers to instructional methods intended to meet the individual needs of different students. Adaptive instruction provides interventions to address individual differences in students' understanding to help each student acquire essential knowledge and skills (Park & Lee, 2003). Park and Lee (2003) noted that "since at least the fourth century BC, adapting has been viewed as a primary

factor for the success of instruction, and adaptive instruction by tutoring was the common method of education until the mid-1800s" (p. 651). In today's classrooms however, some students fall behind as their teachers move onto to new material before they have had sufficient time to master the current content (Schunk, 2012).

Glaser (1977) described three essential elements of adaptive instruction. First, adaptive instruction provides a variety of goals and instructional paths from which students may choose. Second, instruction is adapted to the students' individual strengths and weaknesses. Third, instruction is designed to strengthen individual abilities and develop the necessary skills for students to succeed in more complex environments.

Adaptive instruction includes alternative instructional methods and resources as well as flexibility in the amount of time students are given to learn. Macaruso and Rodman (2011a) contended that CAI effectively adapts instruction by enabling "students to work at their own pace so that they receive sufficient independent practice" (p. 173). Park and Lee (2003) contended that adaptive instruction is a fundamental goal of CAI and that adapting instruction to each student's unique needs makes instruction the most powerful. This single factor may account for the impact of CAI on learning.

Mastery Learning. Timely feedback and adaptive instruction to facilitate mastery are cornerstones of mastery learning. In mastery learning, learning objectives are identified along with levels of mastery for each. Instruction is planned for each objective and students receive corrective feedback on their progress toward learning each objective through formative evaluation. Students receive corrective instruction if they do not master the objectives of the unit and are provided with additional time for remedial instruction and intervention (Schunk, 2012). The mastery learning approach is prevalent

in computer assisted instruction and heralds back to Skinner's early teaching machines that delivered sequenced and segmented instruction to students, provided feedback on each response, and adapted subsequent instruction based on the accuracy of responses to the current frame. Cheung and Slavin (2011) noted that from the earliest advent of CAI in the 1970s, its most frequently cited benefit has been "the capacity to completely individualize the pace and level of instruction to the needs of each child" (p. 202). CAI provides the means for teachers to determine students' current level of understanding, provide the next steps in a learning progression, allow individual pacing, and provide support and scaffolding for students who struggle. Schunk (2012) noted that computer assisted instruction is "firmly grounded in learning theory and research" including providing immediate feedback, which may be more comprehensive than what teachers typically provide, such as comparing current performance to past performance, individualizing content and the rate of instruction, and adapting instruction to students' individualized needs (p. 109).

Lee and Park (2008) stated that the development of CAI has enabled more powerful and sophisticated adaptive systems that include embedded diagnostic assessment as well as micro-adaptive instruction that uses ongoing embedded assessment to diagnose students' individual learning needs and prescribe and provide individually tailored instruction to meet those needs. As an example, Macaruso and Rodman (2011a) described the branching system built into the Lexia Reading platform that allow students "to progress to higher units and more complex skills within an activity only when [they have] mastered basic skills" (p. 176). If students make the same mistake repeatedly, the program branches to provide additional practice on the necessary identified skills.

Motivation. Much of behaviorist theory centers on how reinforcements and consequences motivate us to learn new behaviors. Skinner (1968) posited that "programmed instruction is primarily a scheme for making an effective use of reinforcers, not only in shaping new kinds of behavior but in maintaining behavior in strength" (p. 146). Skinner (1968) theorized that programmed instruction could provide students with an automatic, systematic, intermittent, and continuous schedule of reinforcement that would have a long-term impact on students' motivation to learn. Wild (2009) stated that increasing student motivation has been a frequently cited benefit of integrating computer applications into instruction. CAI has been found to have a positive impact on student motivation, even with drill-and-practice types of applications (Tillman, 2010; Wild, 2009). Fälth, Gustafson, Tjus, Heimann, and Svensson (2013) found that CAI design can increase student motivation by presenting instruction through dynamic graphics and providing immediate feedback. Wild (2009) further noted that in addition to the embedded reinforcers of awarding points, pictures or sounds, CAI can also "foster intrinsic motivation by incorporating features that promote learner autonomy and control" (p. 417).

Research on the Impact of CAI on Reading Achievement

Overview

Due to the extensive amount of research on the impact of technology on student learning, as well as reading achievement, a number of meta-analyses have been published that synthesize and summarize the findings of individual studies. This section of the literature review will begin with a summary of key meta-analyses of computer-adaptive

instruction in general, followed by the impact of CAI on reading outcomes and conclude with studies on the effect of the Lexia Core5 reading intervention program.

Effect Size. Effect sizes indicate the magnitude of the effect of the independent variable and are the key finding in meta-analysis research. Glass introduced the metric of effect sizes to represent the difference in means of an experimental and a control group expressed in standardized units, typically derived by dividing by the standard deviation. The effect size can be converted to a percentile difference between treatment and control groups making it simple to interpret. Effect size is also not unduly affected by sample size (Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011, p. 11). Reading interventions are considered to be effective if they demonstrate effect sizes greater than 0.13–0.23 (Kyle, Kujala, Richardson, Lyytinen, & Goswami, 2013).

Second-Order Meta-Analysis of Computer-Assisted Instruction

In a second-order meta-analysis, Tamim, Bernard, Borokhovski, Abrami, and Schmid synthesized findings from 25 meta-analyses encompassing over 1,000 primary studies on the impact of technology on student achievement. The authors found a mean effect size of 0.35 for the use of technology, which was significantly higher than the control group. The authors noted that these results are highly consistent other second-order meta-analyses such as that conducted by Hattie (2012), who also found an effect size of 0.31 for the impact of technology on learning. Cheung and Slavin (2011) found a similar result in their review of major meta-analyses conducted since the 1990s, showing convergent findings that technology has small to moderate effects on reading outcomes (ES = +0.06 to +0.43).

Drilling down into the results, the researchers found a low to moderate effect size for the use of technology as direct instruction (ES = .31) and a slight, but significantly higher difference for using technology to support instruction. These findings confirmed research by Schmid et al (2009) who also found significantly higher outcomes for using technology as a support for cognition as opposed to delivering instruction. The authors concluded that the "strengths [of technology] may lie in supporting students' efforts to achieve rather than acting as a tool for delivering content" (Tamim et al., 2011, p. 17).

Meta-Analyses of the Effect of CAI on Reading Achievement

A number of different meta-analyses have been published that examine the effect of CAI on students' reading achievement. This section will provide a review of these studies.

In 2000, Soe, Koki, and Chang reviewed 17 studies from the 1980s and 1990s that met the criteria for inclusion in their meta-analysis of the impact of CAI on reading achievement for K-12 students (2000). The authors found that CAI had a positive, but small effect on reading achievement (ES = 0.13). The researchers used a weighted Z value to account for the different sample sizes included in the meta-analysis. The authors noted that while the effects were not homogenous among the studies, they were unable to identify any common characteristics that accounted for the differences (Soe et al., 2000).

Hall, Hughes, and Filbert (2000) reviewed six studies that used CAI as a treatment condition and traditional instruction as a control condition for reading achievement by students with learning disabilities. In four of the six studies, CAI provided a significant difference on students' growth in reading. Hall et al. (2000) further found that elaborated feedback was a significant intervening variable for students who

received CAI intervention. CAI programs that provided students with detailed and strategic feedback and opportunity to relearn the content resulted in higher learning outcomes than programs that simply informed students whether their response was correct or incorrect. CAI programs were found to be equally effective for students learning both decoding and comprehension strategies and using either a drill-and-practice or strategy instruction approach (2000). Tillman (2010) found convergent results in a later review of research, finding supporting evidence that CAI positively impacted reading growth for students with disabilities. Drilling down, Tillman found evidence supporting the effectiveness of CAI in improving text decoding skills and phonological awareness (2010).

In 2012, Cheung and Slavin (2011) reviewed 84 studies on the impact of CAI on reading achievement that included over 60,000 K-12 students. Like earlier studies by Dynarski et al (2007) and Kulik and Kulik (1991), Cheung and Slavin found a significantly positive but small effect (ES=+0.16) for CAI compared with traditional instruction (Cheung & Slavin, 2011). In this meta-analysis, Cheung and Slavin also classified CAI applications as (a) supplemental instruction that provide supplemental instruction directed at students' individual needs as assessed by the software program, (b) comprehensive instruction that integrate computer-assisted instruction with traditional curriculum and instruction to provide a comprehensive instructional model, (c) small-group instruction that provide small-group interventions that are tightly integrated with the regular reading curriculum and instruction, or (d) innovative. Cheung and Slavin (2011, 2012) found that studies on CAI used for supplemental instruction with large sample sizes typically showed smaller effect sizes (ES=-0.01 to +0.11) than other

classifications of CAI. However, Lexia and Jostens demonstrated more promising effects. From this study, Cheung and Slavin suggested that the most common uses of CAI may not have a meaningful impact on students' reading achievement (2011). However, they did find larger effect sizes (ES= +0.28) for comprehensive models such as Read 180 that serve as integrated reading interventions, combining CAI with traditional instruction as well as extensive professional development (2011, 2012). Interestingly, in a follow-up meta-analysis, however, Cheung and Slavin found that small-group integrated interventions had the highest effect size as shown in Table 2. The authors contended that the higher impact on small-groups was expected, citing previous research supporting the effectiveness of small-group instruction for struggling readers. Such small-group interventions tightly integrate with existing curriculum to provide targeted and systematic instruction which may resulting in greater impact on struggling students' reading outcomes (Cheung & Slavin, 2013).

Table 2 Effect Size by Classification of CAI

Classification	Effect size		K	
	2011	2013	2011	2013
Computer-managed	.19		4	
Supplemental	.11	.18	56	12
Comprehensive	.28	.04	18	3
Small-group	n/a	.32	n/a	3
Innovative	.18	.18	6	2

Note. The 2011 data are from "The Effectiveness of Education Technology for Enhancing Reading Achievement: A Meta-Analysis" by A.C. Cheung and R.E. Slavin, 2011, *Best Evidence Encyclopedia.* Copyright 2011 by the Center for Research and Reform in Education. The 2013 data are from "Effects of Educational Technology Applications on Reading Outcomes for Struggling Readers: A Best-Evidence Synthesis" by A.C. Cheung and R.E. Slavin, 2013, *Reading Research Quarterly*, *48.3.* Copyright 2013 by the International Literacy Association. Used with permission.

Cheung and Slavin (2012) also categorized existing research according to Table 3. The researchers noted that typically the effect sizes in small studies were about twice that of large studies. Cheung and Slavin (2013) also found the effect size of CAI for students in primary grades (ES=+0.36) was over five times higher than the effect size for students in upper elementary grades (ES=+0.07).

Table 3 CAI Effect Size by Classification of Study and Sample Size

	Experimental	Quasi-experimental	Overall
Small	+0.21	+0.24	+0.25
Large	+0.07	+0.16	. +0.13
Overall		+0.19	

Note. Data from "How Features of Educational Technology Applications Affect Student Reading Outcomes: A Meta-Analysis" by A.C. Cheung and R.E. Slavin, 2012, *Educational Research Review.* Copyright 2012 by Elsevier. Permission pending.

Other researchers, however, have found contradictory results. Shannon, Styers, Wilkerson, and Peery (2015) noted that while research on the effectiveness of CAI has surged recently, findings for its impact on early reading have shown mixed results. Khan and Gorard (2012) also cited "a number of studies and systematic reviews [of] software [that] had no effect on reading achievement" noting that "rigorous intervention studies with suitable controls often find little or no positive impact from the use of technology-based instruction compared to standard or traditional practice" (p. 23).

While the meta-analysis approach provides a method of synthesizing the findings from large numbers of studies that have been done on the impact of CAI on reading achievement, it also has its drawbacks. For example, Archer et al. (2014) argued that, "the variation across studies in factors such as sample size, types of ICT/CAI employed, and design of the study, however, make it difficult to reach clear conclusions about the overall effectiveness of literacy based ICT/CAIs" (p. 140). The authors noted that the lack of clarity and consistency in defining CAI makes investigating its effects especially challenging. Types of technology, purpose of technology, and methods of implementation all present confounding variables in the research. Similarly, Cheung and Slavin (2011) contended that the difference in reported effect sizes between large and

small sample sizes may result from the ability of "researchers to maintain high implementation fidelity in small-scale studies as compared to large-scale studies" ensuring that the technology is implemented the way that is was designed to (p. 20). Therefore, Archer et al. (2014) contended that further research is necessary to understand whether specific features of the CAI implementation impacts their effectiveness.

Key Studies of the Impact of CAI Intervention on Early Reading Skills

The Stanford Project

One of the earliest investigations into the effect of CAI on reading achievement was the Stanford project by Atkinson and Hansen in 1966. Atkinson and Hansen (1966) described the development of a comprehensive computer assisted instructional program for early reading skills that selected reading exercises based on students' performance on earlier exercises, allowing students to "progress at [their] own pace through a subset of materials designed to be best suited to his particular aptitudes and abilities" (p. 7). While the program was not able to replace the classroom teacher, as originally intended, students who participated in supplemental computer-assisted reading instruction for eight to ten minutes per day achieved higher reading scores than the control group. However, the Stanford program was discontinued, likely due to the high cost of mainframe computers and the number of complex peripherals, including light-pens and touch screens, that were necessary to support it (Blok, Oostdam, Otter, & Overmaat, 2002).

Subsequent Studies on CAI for Reading Intervention

Fälth, Gustafson, Tjus, Heimann, and Svensson (2013) found that gains in both decoding skills, reading fluency, and reading comprehension could be achieved through participation in CAI interventions targeting both reading comprehension and

phonological awareness. During the intervention, special education teachers actively encouraged participation and individualized the degree of difficulty of CAI instruction to meet individual students' needs. These gains persisted over a one-year follow up and effectively reduced the gap between typical readers and at-risk readers: at-risk readers in the treatment group gained three more standard deviations on the sight word reading assessment than their typical peers. Similarly, Saine, Lerkkanen, Ahonen, Tolvanen, and Lyytinen (2011) found that CAI remedial reading instruction was more effective than traditional intervention in improving outcomes in letter knowledge, reading accuracy, fluency and spelling for at-risk students. The study showed that the children in the CAI group made gains during the first grade and continued to progress similarly in follow-up assessments conducted 12 months (second-grade) and 16 months (third-grade) after the intervention had ceased. Like the students in the study by Fälth et al. (2013), the at-risk students reduced the learning gap between themselves and their typical peers and the gains continued in the year following the intervention. These results support earlier findings by Mioduser, Tur-Kaspa, and Leitner (2000) that CAI-based instruction led to significantly higher gains in phonemic awareness skills, word recognition, and letter naming skills.

Gibson, Cartledge, and Keyes (2011) also found significantly positive gains in oral reading fluency, reading growth rates, and reading comprehension for students who participated in a CAI supplemental reading program. Students participated in the intervention three to four times each week for a period of 14 to 16 weeks. All participating students increased their reading fluency and reading comprehension scores from their pre-test scores. The CAI intervention used research-based instructional

strategies including goal-setting, vocabulary pre-instruction, and repeated readings. Findings of a follow-up study in 2017, Bennett, Gardner III, Cartledge, Ramnath, and Council III (2017) showed a positive effect on reading fluency and that participants' growth rates in reading exceeded the growth rates for typical peers. The software program combined repeated readings with culturally relevant stories. The researchers concluded that at-risk second-grade students need both culturally relevant reading content and consistent practice with fluency skills to make the necessary gains to become grade-level readers. Student responses indicated that the intervention was both motivating and reinforcing.

In a longitudinal analysis, Cassady and Smith (2005) found significant gains in reading achievement of first-grade students who participated in the *Waterford Early Reading Program* (WERP). Students whose reading achievement was below the 25th percentile demonstrated the highest gains in reading achievement. The authors asserted that the efficacy of WERP was principally due to its alignment with state standards and the reading curriculum, as well as the school vision for developing literacy. These findings were consistent with those found by Hecht and Close (2002) whose research showed higher outcomes on measures of phonological awareness and word reading for students who participated in WERP (Macaruso & Rodman, 2011b). Cassady and Smith (2005) also noted that teachers monitored students' progress, adjusted classroom instruction, and modified the instructional program to ensure students were engaged in the right level of content. Finally, they also noted that schools need a clear plan to support implementation to ensure its success.

Putman (2017) also found a statistically significant effect on early literacy skills for kindergarten students who participated in the Istation reading intervention program. Istation had the most significant impact on literacy skills that require drill and repeated practice including letter sound knowledge, the ability to hear and record sounds, and writing vocabulary. Istation effectively scaffolded students' learning and provided targeted instruction within students' zones of proximal development; however, more complex early literacy skills such as reading and comprehending texts and understanding concepts about prints appeared to require interactive instruction and feedback from a teacher to allow students to participate more actively in the interaction.

Research on the Impact of Lexia Core5

Lexia Early Reading

Lexia Early Reading is an earlier version and precursor to Lexia Core5. Macaruso and Walker (2008) found significantly higher achievement on the *Gates-MacGinite Reading Test* for kindergarten students who completed a minimum number of activities in Lexia Early Reading. To control for teacher and classroom confounding variables, matched classes from the same instructor in the same classroom were randomly assigned to either the treatment or the control group. The mean NCE for the treatment was 54.2 compared to 46.4 for the control group, a significantly higher result. The treatment group demonstrated higher achievement on each subtest; however, only the difference on the phonemic awareness subtest was statistically significant. The effect size for at-risk students (ES = 1.56) was significantly higher than the control group (ES = .48) as well, suggesting that Lexia was particularly effective for the most at-risk students.

Lexia Primary Reading. In a follow-up study, Macaruso and Rodman (2011b) found that while all kindergarten students showed gains in early literacy skills from the pre-test to the post-test, those who participated in Lexia Reading made significantly higher gains than their peers in the non-CAI comparison group. The results also supported earlier findings that CAI intervention had an even more significant impact for the students who were most at-risk on the pre-assessment.

Lexia Core5. In a randomized control trial, O'Callaghan, McIvor, McVeigh, and Rushe (2016) found that Pre-K and kindergarten students who participated in Lexia made higher gains in both phonological awareness and fluency than their peers who received standard classroom instruction. However, the researchers noted that students did not see the same gains in phonemic awareness and that about one-third of the students did not show benefits from the instruction, which is typical of both CAI and traditional interventions.

Similarly, Schechter, Macaruso, Kazakoff, and Brooke (2015) found that low socioeconomic first and second-grade students who participated in Core5 also made statistically significant higher gains on tests of reading achievement compared with peers who received regular classroom instruction with a moderate effect size of .53. At the subtest level, students in the CAI treatment made significantly higher gains in text comprehension; however, vocabulary gains were statistically similar between both groups.

Key Factors in Research on CAI.

Several key factors may contribute to the variation in outcomes among the research on CAI, including fidelity of implementation and teacher training and support.

Research has shown that technology integration in education can be influenced by a number of different factors. For example, Wozney, Venkatesh, and Abrami (2006) found that teaching styles, personal computer use, and technology-related training all played a role in how technology was used in the classroom as well as how much technology was being used. Similarly, Mueller, Wood, Willoughby, Ross, and Specht (2008) found that experience with and attitude towards technology was a major factor in classroom integration. It can be expected that the implementation of a technology-based intervention might be similarly influenced by a teacher's comfort, attitude and use of computers.

Fidelity of Implementation. Archer et al. (2014) stated that even though fidelity of implementation may have a significant impact on results, it is rarely reported or measured in studies, especially when the regular classroom teacher is responsible for implementing the intervention. The authors underscored the importance of considering the fidelity with which an intervention is implemented to account for this variable. To ensure that interventions are delivered with fidelity, necessary training and support must be provided to the teachers who implement the intervention (2014)

Teacher Training and Support. Closely related to fidelity of implementation, Archer et al. (2014) also suggest that "training and instruction needs to be a greater focal point in [the] design" of CAI research projects (p. 147). The authors noted that training has been shown to effectively impact teachers' integration of technology into their instruction. Ongoing support is necessary for teachers to gain sufficient expertise and skills to be able to problem-solve the issues that arise during implementation. Therefore, providing both adequate training and support can impact the effectiveness of CAI interventions throughout the duration of the intervention (Archer et al., 2014).

Instructional Strategies. It is assumed that such intervention will help students improve their reading skills by providing guided practice on skills, immediate and individualized feedback, and increasing motivation through a sense of accomplishment (Lovell & Phillips, 2009). As famously argued by Clark (1983), "it is the method of instruction that leads more directly and powerfully to learning" (p. 449). Mioduser et al. (2000) noted that after decades of implementing computer technology into instruction, that "technology by itself means only the necessary infrastructure upon which should be built robust pedagogical solutions to real learning problems" (p. 61). Therefore, the actual instructional strategies embedded in the CAI design are fundamental to its effectiveness as an intervention. Hall, Hughes, and Filbert (2000) identified common instructional strategies that are embedded in CAI, including strategy instruction, drill-and-practice, simulations, tutorials, writing, and problem solving. Of these, drill-and-practice is the most frequently used strategy in CAI interventions. Hall et al. noted that well designed drill-and-practice must include corrective feedback and reinforcement with a focus on students repeating skills (2000).

Need for Further Research

Technology has been widely accepted as an important resource in K-12 education. And more specifically, parents and students assume that CAI will provide struggling students with necessary practice and support on fundamental reading skills. However, the effectiveness of any CAI intervention is inherently dependent on its instructional design, and it stands to reason that not all CAI interventions are created equal. Soe, Koki, and Chang (2000) noted that among the expected benefits of CAI are "vastly superior materials and more sophisticated problems" as well as adaptive instruction and embedded

assessment (p. 8). However, Lovell and Phillips (2009) argued that the existing research on the impact of CAI contains programs that do not meaningfully integrate technology into instruction or that are non-instructional, lacking the ability to track student progress, provide feedback and adaptive instruction. For that reason, Santoro and Bishop (2010) argued for the necessity of "us[ing] empirically supported criteria to valuate reading software applications" (p. 99). The authors proposed four criteria as a framework to evaluate the design of CAI program: (a) interface design, (b) instructional design, (c) phonological skills, and (d) alphabetic understanding. Using these criteria, Santoro and Bishop (2010) found significant variation in scores for CAI programs and that as a whole, the sample they reviewed "did not meet research-based criteria for interface, instructional design, and beginning reading content required for at-risk learners" (p. 114).

Gibson, Cartledge, and Keyes contended that CAI (2011) "software programs are finding their way into classrooms across the country without a valid empirical research base to back up their claims, possibly increasing student risk by wasting valuable learning time" (p. 264). Shannon, Styers, Wilkerson, and Peery (2015) concurred with this contention: "as teachers seek to supplement classroom reading instruction with new technological resources, there is a need for data regarding the degree to which specific computer-assisted learning programs might contribute to student learning in reading" (p. 21). However, there is only limited research and knowledge on how CAI compares with traditional classroom instruction on improving students' reading achievement (Fenty et al., 2015). Lovell and Phillips (2009) contended:

> [CAI] manufacturers' claims are often sweeping, and although they use educational vocabulary, claims of educational gains are not supported by evidence

> from experimental trials and systematic analyses. . .. Consequently, teachers, schools, and school boards face yet another shortcoming in the amount of reliable and valid evidence to determine whether or not programs are pedagogically appropriate or effective (pp. 211–212).

Therefore, Fenty, Mulcahy, and Washburn (2015) advocated for the importance in further research "to determine whether CAI is a valid alternative to teacher-led instruction [and] justify providing CAI as an alternative method for increasing reading skills" (p. 142). This need has not changed from the time it was first identified by the National Reading Panel in 2002 who stated that the quality of instructional software for early reading instruction and intervention "needs a great deal of additional exploration" (2000a, Chapter 6, page 2).

CHAPTER THREE: METHODOLOGY

Introduction

In response to legislative mandates to implement more intensive interventions for students who read below grade-level, the Washington School District adopted the Lexia Core5 reading program as its primary early literacy intervention. The purpose of this research study was to determine whether the use of the Lexia program had an effect on gains in student reading and to learn what key factors may influence those gains. A mixed methods approach employing an explanatory sequential design was used to understand how the Lexia Core5 reading program influences second-grade students' gains in reading achievement. The quantitative analysis employed an independent samples t-test, ANOVA test, and multiple regression analysis to analyze the correlation between predictor variables and the outcome variable: gains in percentile scores on the Star Reading assessment. Quantitative analyses were performed using the IBM SPSS statistical analysis software. The researcher followed the quantitative analyses with a qualitative phase to provide elaboration and explanation of the quantitative results. Teachers were purposefully sampled from the quantitative results for semi-structured interviews. These interviews were coded and analyzed to identify common themes among the teachers' beliefs and practices of CAI in general and Lexia Core5 in specific.

Statement of the Problem

Like many other districts in Idaho and across the United States, Washington School District has adopted computer-assisted instruction in an effort to help all students

become proficient readers. The District's strategic plan for improvement has identified a goal that 95% of third-grade students will demonstrate reading proficiency by 2025 and implementing Lexia Core5 is identified as a key strategy to accomplish that goal. Research investigating the impact of CAI is important to address concerns such as those expressed by Gibson, Cartledge, and Keyes (2011) who stated that commercial "software programs are finding their way into classrooms across the country without a valid empirical research base to back up their claims, possibly increasing student risk by wasting valuable learning time" (p. 264). For that reason, it is critical for the Washington School District to know what effect the adopted software program has had on student reading gains and what key factors may influence those gains. These results will also inform other school districts with similar technology adoptions.

Research Methodology

The study employed a mixed-methods approach to answer the research questions. The researcher has typically adopted a pragmatist worldview in approaching research questions. A pragmatist view is concerned with understanding what works and identifying solutions to problems (Creswell & Creswell, 2018). From the pragmatist view, mixed methods research allows both quantitative and qualitative data to be used to find the best understanding of a research problem (Creswell & Creswell, 2018). Mixed methods designs have been recognized for their usefulness in implementation research because "the challenges of implementing evidence-based and other innovative practices, treatments, interventions and programs are sufficiently complex that a single methodological approach is often inadequate" (Palinkas et al., 2015, p. 1). Creswell and Creswell (2018) explained that mixed methods research can "develop a stronger

understanding of the research questions . . . [and] more insight into a problem is to be gained from mixing or integration of the quantitative and qualitative data" (p. 213).

District and state leaders often desire hard-data, seeking to know simply whether a software program, or a curricular resource, or a particular instructional strategy works or doesn't work. Therefore, quantitative analysis is important because it is ideally suited for determining "whether an educational practice makes a difference for individuals" (Creswell, 2012, p. 20). At the same time, quantitative data has pragmatic limits in real-world contexts because of the many factors that influence student learning. Simply understanding whether or not participation in a particular CAI application provides an important, but limited answer. Qualitative research provided deeper insight into understanding how key factors may influence quantitative outcomes.

Research Design

An explanatory sequential mixed methods design was employed to understand how the Lexia Core5 reading program influenced second-grade students' gains in reading achievement. In the first phase, quantitative data were analyzed using an independent samples t-tests to answer the first research question. Key factors with a significant effect were then identified using Analysis of Variance and multiple regression analysis methods to answer the second research question. In this step, teachers whose classes showed exceptional gains were identified. These teachers were purposefully selected from the quantitative results to participate in interviews in the qualitative phase of the study (Creswell & Creswell, 2018, p. 221). Results from the quantitative data also informed the questions for the semi-structured interview instrument in the qualitative phase (Creswell

& Creswell, 2018, p. 221). Qualitative data were then analyzed to help explain the results of the quantitative analysis.

Participants and Sampling

Population

This research study was conducted in the Washington School District, a suburban school district in Idaho with a student population of approximately 10,000 students. The Deputy Superintendent and the Director of Instruction and Learning granted permission to the researcher to complete this research study. Letters of approval are included in Appendix C.

The district has a historic free-and-reduced lunch (FRL) rate of between 40% and 45%. The FRL rate among elementary schools ranges from 11.5% to 60% with one school qualifying for a program where all students are automatically qualified for the FRL program. On average, 19% of the students are racial minorities with 75% of the minority students identifying themselves as Hispanic. The district has experienced a 3% average annual growth rate in student enrollment over the past two decades.

For the research project, the participants selected for this study were second-grade students enrolled in the district in each of the following school years: 2013-2014, 2014-2015, 2015-2016 and 2017-2018. Teachers assigned to teach second-grade in the 2017-2018 school year participated in the qualitative phase of the research project.

On the spring state early reading assessment, known as the Idaho Reading Indicator (IRI), students in the Washington School District have typically performed above the state average. As shown in Figure 6, the percentage of second-grade students

reading at grade level increases by an average of 17% from fall to spring each year. This is typically 3% higher than the statewide average increase.

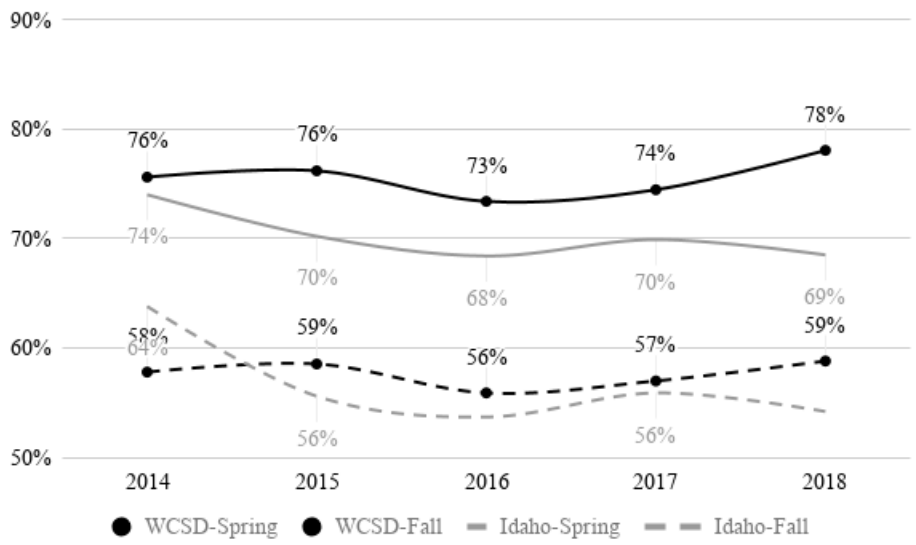

Figure 6. WCSD and State Second-grade Idaho Reading Indicator Results

Quantitative Phase

To address the first research question, student scores on the Star Reading assessment were collected from the 2014, 2015, 2016, and 2018 school years. Student enrollment in second-grade ranged between 900 and 1,000 students each year across the district's 14 elementary schools for a total population size of approximately 3,800 students in this phase of the research study.

To answer the second research question, the researcher analyzed scores from second-grade students on the Star Reading Assessment from the 2018 school year only, which was approximately 940 students. Second-grade is a critical year in the development of students' reading ability as students should have progressed from the early literacy stages where reading skills typically work as discrete functions to the beginning reading and writing stage where reading skills begin to function in

synchronicity enabling students to begin reading fluently and with comprehension (Cooper et al., 2017). The Committee on Prevention (1998) noted that "in school lore, second-grade is broadly viewed as children's last chance. Those who are not on track by third-grade have little chance of ever catching up" (p. 212).

Sample. Scores were used from all second-grade students who met the following criteria for inclusion. First, to derive growth scores, for both participants and non-participants, only students with fall pretest and spring posttests scores were included. Second, in the analysis for the first research question, students who did not participate in the Lexia program for at least 30 hours were excluded from the study. 30 hours was selected as the minimum threshold to align with state legislation requiring at least 30 hours of intervention for students who were below grade-level on the state fall reading assessment. To answer the second research question, all students who participated in both the fall and the spring Star Reading assessment were included as number of hours of participation was included as one key factor in the multiple regression analysis.

Qualitative Phase

For the qualitative phase, second-grade teachers were purposefully sampled for interviews using the extreme case strategy. Palinkas, Horwitz, Green, Wisdom, Duan, and Hoagwood defined purposeful sampling as the method of "identifying and selecting individuals or groups of individuals that are especially knowledgeable about or experienced with a phenomenon of interest" (Palinkas et al., 2015, p. 2). Palinkas et al (2015) further explained that the selection of a purposeful sampling strategy must be done with consideration to the impact of the strategy not only on the objectives of both the quantitative and qualitative methodologies, but also on the overall purpose of the

research design (p. 80). The extreme case strategy is used to identify extreme cases that "illuminate the nature of success" (Palinkas et al., 2015, p. 2). Therefore, for this explanatory sequential mixed methods design, the extreme case strategy was the most appropriate method to learn from those teachers who would best be able to explain high gains on the Star Reading assessment (Creswell & Plano Clark, 2018, p. 80). Using this strategy, the researcher selected those teachers whose classes showed exceptional gains in reading achievement for interviews. The researcher used one standard deviation above the norm as the delimiter to define "exceptional gains." Five teachers were identified whose mean reading gains met this threshold.

Instrumentation and Data

Quantitative Instrumentation

The instrument used for the quantitative analyses was the Star Reading assessment, a computer-adaptive test that assesses students' reading achievement as well as discrete reading skills aligned to the Common Core standards (Renaissance Learning, 2017). The Star Reading Assessment is taken each year by approximately six-million students in the United States. According to its publisher, Renaissance Learning, Star Reading has three purposes: (a) to "provides educators with quick and accurate estimates of reading comprehension," (b) to "assess reading achievement relative to national norms", and (c) to track longitudinal growth in reading achievement consistently for all students (Renaissance Learning, 2017, p. 2). Results are used at the classroom, school, district and in some cases, state levels to make instructional decisions to improve student reading achievement. Star Reading has been normed nationally and has been shown to

have high degrees of reliability and validity in determining students' level of reading comprehension and reading achievement.

As a computer-adaptive assessment, Star Reading uses "Adaptive Branching" to improve test reliability, decrease testing time, and enhance student motivation. This approach "was designed to yield reliable test results for both the criterion-referenced and norm-referenced scores by adjusting item difficulty to the responses of the individual being tested while striving to minimize test length and student frustration (Renaissance Learning, 2017, p. 6). According to Renaissance Learning, over 95% of students complete the Star Reading assessment in less than 30 minutes (Renaissance Learning, 2017).

Norming. The most current version of Star Reading is a standards-based assessment that measures students' progress on instructional standards in addition to overall reading comprehension. The latest norming for Star Reading occurred following the 2014-2015 school year. Stratified sampling procedures for grade-level and decile ranking were used. Further steps were used to ensure the samples adequately represented race, socioeconomic status, and geographical residence characteristics of the United States K-12 school enrollment. Results of the norming process are depicted in Figure 7 below.

	Fall Unified Scale Scores				Spring Unified Scale Scores			
Grade	N	Mean	Standard Deviation	Median	N	Mean	Standard Deviation	Median
K	212,035	702	62	703	196,720	795	65	793
1	340,079	776	72	767	237,360	857	69	856
2	456,566	887	70	888	264,790	939	66	942
3	419,912	952	67	956	299,620	987	64	990
4	447,754	994	64	999	308,040	1,021	65	1,023
5	364,271	1,031	65	1,036	244,750	1,055	67	1,058
6	219,348	1,063	67	1,067	125,070	1,085	70	1,089
7	128,011	1,087	71	1,090	73,830	1,104	74	1,108
8	94,691	1,109	73	1,114	43,980	1,126	77	1,130
9	25,063	1,128	78	1,131	25,240	1,138	76	1,143
10	35,198	1,138	75	1,143	22,720	1,143	77	1,150
11	25,660	1,143	75	1,150	9,380	1,150	75	1,157
12	18,092	1,153	76	1,161	4,230	1,158	76	1,165

Figure 7. Star Reading Norming Results.

From *Star Assessments® for Reading Abridged Technical Manual* by Renaissance Learning, Inc., 2017, Wisconsin Rapids, WI: Renaissance Learning, Inc. Reprinted with permission.

Reliability and Measurement Precision. The Star Reading Assessment provides reliability coefficients and standard errors of measurement to evaluate the reliability of its scores (Renaissance Learning, 2017). A large sample of student results from the 2012-2013 school year showed that Star Reading had a generic reliability coefficient of .97. However, this theoretical estimate is generally higher than more conservative forms of reliability coefficients. Calculations using the alternate split-half reliability method showed an overall reliability coefficient of .93 and .85 for second-grade with an average span of 105 days between assessments (Renaissance Learning, 2017). These findings have been validated by independent organizations including the National Center for

Intensive Interventions and the Center on Response to Intervention ("Center on Response to Intervention," n.d.; "National Center on Intensive Intervention," n.d.).

Validity. Validity refers to the accuracy of assumptions that can be made about results gleaned from a particular assessment. Two constructs for measuring the validity of an assessment are content validity and construct validity (Popham, 2010).

Content Validity. Popham (2010) defined content-related evidence of validity as "the degree to which an assessment satisfactorily represents the content domain being measured" (p. 23). The Star Reading Assessment is comprised of more than 5,000 items organized within 36 reading skills and the following five domains of reading: (a) word knowledge and skills, (b) comprehension strategies and constructing meaning, (c) understanding author's craft, (d) analyzing literary text, and (e) analyzing argument and evaluating text. A chart of the five domains, skill sets, and skills is included in Appendix A. Items were developed and reviewed to ensure its validity on multiple factors including adherence to skills, readability, cognitive load, content differentiation, bias and fairness, content accuracy, and language components (Renaissance Learning, 2017).

Construct Validity. Popham (2010) describes content validity as twofold: "(1) demonstrate[ing] that the hypothesized construct actually exists and (2) show[ing] the test . . . under scrutiny does, in fact, accurately determine a test-taker's status with respect to the hypothetical construct" (p. 35). For Star Reading, this means determining whether it accurately measures students' ability to read and comprehend what they have read. To evidence Star Reading's construct validity, Renaissance Learning has conducted hundreds of different linking studies, the results of which are shown in Table 4. The overall average within-grade concurrent validity coefficient was .74 for grades 1-6 with a

range of .72 to .80. Furthermore, summaries of 300 coefficients of correlation showed a predictive validity coefficient range of .69 to .72 with a mean of .71 in grades 1-6 (Renaissance Learning, 2017). A meta-analysis of 569 Star Reading correlations showed a validity coefficient of .78 with a 95% confidence level (Renaissance Learning, 2017).

Table 4 Star Reading Predictive and Concurrent Validity Data

	K-6th Grades	2nd Grade
Concurrent validity data		
Number of students	255,538	3,629
Number of coeffecients	195	18
Average validity	0.74	0.73
Predictive validity data		
Number of students	1,227,887	188,434
Number of coeffecients	194	10
Average validity	0.71	0.72

Note. Data from *Star Assessments™ for Reading Abridged Technical Manual* by Renaissance Learning, Inc., 2017. Wisconsin Rapids, WI: Renaissance Learning, Inc. Used with permission.

Qualitative Data

The qualitative phase of the research project consisted of semi-structured interviews of those teachers who were identified as having had exceptional gains on the Star Reading assessment. Using results from the quantitative analysis, the researcher developed a semi-structured protocol to interview participants selected for the qualitative phase. The interview protocol identified key questions to elicit open-ended responses from participants (Creswell & Plano Clark, 2018). This protocol consisted of the following key questions:

- Why do you think students have had higher-than expected reading achievement in your classroom this year?
- What are your thoughts about the Lexia reading program?
- What do you typically do while students are using Lexia in your classroom?
- How have you learned to implement the Lexia program in your classroom?
- Describe the role that that technology plays in your instruction.

While these questions served as a basic guide for the interviews, the researcher tried to use the guide with caution to allow the teachers to express their own areas of interest and experiences (Seidman, 2013).

Data Management and Collection

Quantitative Data

All second-grade students in the district have normally participated in the Star Reading Assessment at least three times each year as a universal screener since the 2012-2013 school year. Students take the Star Reading assessment before October 1st as the fall screening window and after April 15th as the spring screening window. A mid-year winter screening window also occurs in January. For this research project, the researcher was provided access to data from the following key databases of student information from the Washington School District: (a) the PowerSchool student information system (SIS) provided teacher assignments for each student, (b) Renaissance Place provided student reading achievement scores for the Star Reading test, (c) Lexia Learning provided student Lexia usage information including initial placement level in Lexia, number of levels,

activities, and units completed, and number of hours of participation. The researcher collected and synthesized data from each of these systems into a single spreadsheet that was secured with a password. Students' personally identifiable information (PII) was removed from the data and replaced with randomly assigned identifiers. After removing the PII from the datasets, the results were imported into SPSS for data analysis.

Qualitative Data

Following the collection and analysis of the quantitative data, the researcher purposefully selected teachers for interviews during the qualitative phase. Survey questions were developed and distributed to all second-grade teachers in the Washington School District through the Qualtrics Research Core platform. The online questionnaire included in Appendix B was designed to determine teachers' level of training on the Lexia software and the level of fidelity with which they had implemented the Lexia program including whether they regularly provided direct instruction to students who were flagged for intervention in the program and printed certificates of recognition for students as they completed levels. A composite rating score was calculated for their reported level of implementation.

In the next step, teachers whose students achieved exceptionally high gains from the fall assessment window to the spring assessment window were identified for open-ended follow-up questions to understand their perceptions regarding the implementation of the Lexia program and their own influence on student achievement. Four of the five sampled teachers accepted the invitation to be interviewed. The researcher scheduled interview times with each teacher in her classroom after school but within her scheduled workday. As Seidman (2013) explained, scheduling interviews at times and places that

are convenient to the participant keeps the interview process fair (p. 111). With permission from each participant, all of the interviews were recorded digitally. The researcher also took brief notes during each interview to facilitate active listening and to track ideas for follow-up questions without interrupting the participants (Seidman, 2013). The digital recordings were saved using the Evernote application, which provided password-protected local and cloud-based storage of the files to ensure security for the interviews (Seidman, 2013).

Data Analysis and Procedures

Quantitative Phase

Quantitative data were analyzed in two phases. In the first phase, relevant quantitative tests were used to analyze student gains from the pre-test to the post-test to test the research hypotheses. In the second phase, findings from the quantitative analyses were analyzed to identify classrooms with an average reading gain of at least one standard deviation above the population mean. Teachers of these classrooms were selected to be interviewed to better understand the quantitative results (Creswell & Plano Clark, 2018).

Research Question 1. To answer the first research question, a quasi-experimental pre- and post-test design was employed. This design was necessary because all second-grade students in the Washington School District were enrolled in and using the Lexia program, many for the past two years, eliminating the opportunity for an experimental design. Removing students from the program would have created significant concerns for students and parents. Therefore, second-grade from the current school year students were

identified as the treatment group and previous second-grade students from the school years 2014 through 2016 were identified as the control group.

*Variables***.** The R1 predictor variable was student participation in the Lexia Core5 program. The outcome variable was reading gains from fall to spring on the Star Reading Assessment from the fall screening to the spring screening in May. Reading gains were calculated by subtracting each student's fall percentile rank from his or her spring percentile rank in the spring.

*Analysis***.** An independent samples t-test was used to compare differences in mean reading gains between the treatment and control groups to evaluate H1.

Research Question 2. The classroom is not an isolated laboratory, and a wide number of factors influence student learning. The effect of any instructional strategy or resource may be influenced by these key factors. The purpose of the second research question was to identify which of these factors had a significant effect on student reading gains. These key factors were organized into the following categories: (a) teacher variables, (b) classroom variables, (c) program variables, and (d) student variables.

Teacher Variables. Research has consistently shown that the classroom teacher is a key variable in student learning outcomes (Dean & Marzano, 2012). However, predictor variables in multiple regression analyses must be either "quantitative variables assessed on an interval or ratio scale" or limited-value variables with no more than six categories (Hatcher, 2013, p. 251); therefore, the research needed to transform the assigned classroom teacher variable into an interval scale variable. To do this, the researcher conducted a preliminary one-way between groups analysis of variance to determine whether each student's assigned teacher was a key factor in their reading

percentile gains on the Star Reading assessment. The results of the analysis of variance showed a significant difference in the reading gains among the 42 different classroom teachers; therefore, the researcher used the teacher's mean percentile gain as the interval scale variable for assigned classroom teacher. Each teacher's evaluation score and years of experience were also included as teacher variables.

Learning Environment Variables. Two learning environment predictor variables were included in the multiple regression analysis: class size and Lexia implementation score. Implementation scores were determined from teacher responses to a survey on how frequently they utilized the different elements of the Lexia Core5 program. Responses to the following questions were included in determining the teacher's implementation score:

1. How often do you use the reports in My Lexia to monitor students' progress?
2. How often do you adjust students' intervention time in Lexia based on the Needs Usage report in My Lexia?
3. How often do you provide teacher-led Lexia lessons to students who have been identified on the Struggling report in My Lexia?
4. How often do you print practice activities for students who have been identified on the Skill Builders report in My Lexia?
5. How often do you print certificates for students who have completed levels in Lexia?

Teachers selected one of the following responses to each question: (a) every day, (b) several times each week, (c) several times each month, (d) several times each grading period, (d) several times a year, or (e) never. Responses were scored on a ratio scale from

5 to 0 points; the implementation score variable was calculated by summing the total score for all of the responses.

Program Variables. Two program variables were included in the analysis: the number of hours each student participated in the Lexia software and the number of levels each student completed.

Student Variables. Four variables that have historically been associated with lower reading achievement were identified: (a) racial minority status, (b) low socioeconomic status, (c) special education status, and (d) English as a secondary language. These four dichotomous variables were synthesized into the single scale variable At-Risk Factors with a range from zero (no-at risk factors) to four (all four at-risk factors).

*Analysis***.** A multiple regression analysis was used to identify the predictor variables that had a significant influence on student growth scores. A follow-up ANOVA test was used to analyze the significance of the predictor variables that had a significant effect to answer the second research question.

Qualitative Phase

Following the quantitative analysis of RQ2, five teachers were identified whose reading gains were at least one standard deviation above the group mean. These teachers were asked to participate in a follow-up interview to answer the third research question: Do teachers with high effect sizes on reading gains share common practices, perceptions, or beliefs? Four teachers agreed to be interviewed. Each teacher was assigned a pseudonym to protect the confidentiality of their statements.

Each teacher was interviewed in a semi-structured interview style using the interview protocol included as Appendix B. Each interview was recorded digitally to ensure accuracy, and the researcher transcribed the interviews verbatim. Seidman (2013) stated that "the primary method of creating text from interviews is to record the interviews and to transcribe them [because] each word a participant speaks reflects his or her consciousness" (p. 117).

To answer the third research question, the researcher reviewed and coded transcripts of teacher interviews using action coding to identify common themes and perceptions (Creswell & Plano Clark, 2018; Saldaña, 2016). The researcher identified the most significant codes to identify the major themes of the interviews (Smith, 2015). These themes were used to generate theoretical explanations of the quantitative results, specifically focusing on why identified teachers realized higher than normal gains than their peers.

Coding Process. After each interview was transcribed, the interviews were coded using "process coding" which is also commonly referred to as "action coding" (Charmaz, 2014; Saldaña, 2016, p. 110). In process coding, the researcher only uses gerunds as codes to identify the specific actions participants have taken. Saldaña (2016) specifically discouraged researchers from using descriptive coding for interview transcripts, arguing that this traditional "method will not reveal very much insight into participants' minds" (p. 102). Charmaz (2014) suggested that using gerunds to code data encourages researchers to begin their analysis from the perspective of the respondents. Charmaz (2014) further noted that this approach "goes deeper into the studied phenomenon and tries to explicate it" (p. 124). Following the first phase of process coding, the initial codes

were revised. Some codes were subsumed under other codes creating subcodes and some codes were combined with other codes to create more inclusive topics (Saldaña, 2016). The initial codes were kept fluid during this process. As Seidman (2013) explained, "some categories that seem promising early in the process will die out. New ones may appear. Categories that seemed separate and distinct will fold into each other. Others may remain in flux almost until the end of the study" (p. 128).

In a third phase of coding, two other methods were incorporated into the analysis: magnitude coding and subcoding. With the magnitude coding approach, the researcher added a supplemental alphanumeric or symbolic code to information that had already been coded to indicate intensity, frequency, direction, or evaluative content (Saldaña, 2016, p. 86). Saldaña (2016) noted that this approach is "appropriate for qualitative studies in education . . . that also support quantitative measures as evidence of outcomes" (p. 86). During the magnitude coding phase, the researcher coded data with positive, negative, and neutral symbols to indicate the teachers' evaluative perception of the behavior or process they were describing as shown in Table 5. Subcodes, or second-order tags, were also assigned to a number of datum to provide more specificity for categorization and data analysis (Saldaña, 2016).

Table 5 Codes Used to Indicate Magnitude and Direction of Perceptions

Symbol	Direction and magnitude of statement
--	Strongly negative
-	Negative
/	Neutral
+	Positive
++	Strongly positive

Identified Themes. After individual passages were marked and grouped into categories, they were studied to find thematic connections (Seidman, 2013). Saldaña described themes as extended phrases that identify what the phrase is about or what it means. Themes may be directly observable or may be latent in the information (Saldaña, 2016, p. 297).

Ethical Considerations

The researcher obtained permission from the Deputy Superintendent and the Director of Instruction and Learning of the Washington School District to collect data and conduct the study. The researcher subsequently obtained approval for the research from the Boise State University Institutional Review Board (IRB) for the research. The study qualified for exemption from further review because it only involved normal educational practices in students' normal education setting (Hicks, 2014; Selwitz, Epley, & Erickson, 2017). The approved IRB protocol number is 104-SB18-009. To protect students' privacy, the researcher eliminated students' personally identifiable information (PII) from the data set after receiving it and used randomly generated codes to replace student identification numbers (Hicks, 2014; Selwitz et al., 2017).

Teachers were provided with informed consent forms prior to completing the online questionnaire and participating in the interview. Teachers were apprised of the purpose of the research, informed that their participation in the study was voluntary, and permitted to withdraw from the study at any time they wished. Permission letters from district level administration are included in Appendix C. The form letter used to obtain informed consent is included in Appendix D.

Limitations and Delimitations

This research focused on second-grade students in Washington School District in Idaho. The Star Reading test does not measure foundational reading skills; therefore, results from this research are only generalizable at the second-grade level. Further, while student demographics in this district are not atypical for student demographics in Idaho, they are also not representative of national demographics for second-grade students. The district has significantly smaller percentages of minorities and English Language Learner students than national averages. As a quasi-experimental study, the study also presents certain risks and predictor variables should not be construed as having a causal effect on reading gains.

Presentation of the Results

All results from the study have been included in the dissertation report. Results have also been summarized in presentation format for presentation to the Superintendent and other members of the district leadership team including the Deputy Superintendent, Directors of Learning and Instruction, Technology, and Student Services, as well as to elementary school principals. The district leadership team is evaluating the results from the research to determine whether to continue the implementation of the Lexia program in the district. With permission of the Superintendent, the work may be anonymized and submitted to appropriate journals and conferences.

Summary

This study evaluated the effect of participating in the Lexia Core5 software program on second-grade students' reading achievement and sought to identify the key

factors that may have influenced that effect. To that end, methods listed in Table 6 were used to address the research questions:

Table 6 Methods Used to Investigate Effect of Lexia Core5 on Reading Gains

Research Question	Collected Data	Data Type	Analysis Method
R1. Does participation in the Lexia Core5 reading intervention program have a significant effect on growth in reading achievement?	Star Reading	Quantitative	Independent samples t-test
R2. What key factors may influence the effect of Lexia Core5 program on student achievement?	Star Reading	Quantitative	Multiple regression ANOVA
R3. Do teachers with high gains in reading achievement share common perceptions, beliefs, or practices that may influence the effect of Lexia Core5 on student achievement?	Interviews sampled from extreme cases	Qualitative	Process coding Magnitude coding Subcoding

An explanatory-sequential mixed methods design was employed to answer these research questions. The quantitative phase consisted of two steps. In the first step, an independent samples t-test was used to compare pre-test to post-test reading gains of current second-grade students who have participated in Lexia against past years' second-grade students who never used Lexia. In the second step, a multiple regression analysis was utilized to identify key factors that may have had a significant effect on reading gains. In the qualitative phase, teachers with exceptional results were purposefully sampled for interviews to learn if they shared common beliefs, practices, or perceptions that may have influenced the effect of Lexia Core5 on students' reading gains.

CHAPTER FOUR: RESULTS

Background

The purpose of this study was to learn how teachers may influence the impact of computer adaptive instruction, and specifically the impact of the Lexia Core5 reading program on students' reading achievement. An explanatory-sequential mixed methods research design was employed to achieve this purpose. In an explanatory-sequential design, research is conducted in two phases: first, quantitative data is collected and analyzed, and second, qualitative research is performed to "help explain or elaborate on the quantitative results" (Creswell, 2012, p. 542). The quantitative phase of the research design was designed to first, identify the impact of participation in the Lexia Core5 reading intervention program on reading achievement, and second to identify the unique impact of potential key factors including hours of participation in Lexia, number of levels completed in Lexia, assigned classroom teacher, level of intervention implementation, teacher years of experience, and student at-risk factors. The qualitative phase of the study was designed to identify shared beliefs, practices or perceptions among teachers whose students achieved significantly higher gains to explain how teachers may influence the impact of the computer adaptive instruction.

RQ1. Effect of Lexia Participation on Reading Gains

Description of Population

The population for the quantitative phase of this study was comprised of students enrolled in second-grade in the Washington School District, a suburban school district in

Idaho. Second-grade students from the 2013-2014 school year through the 2017-2018 school year were included, excluding the 2016-2017 school year. Students in the 2016-2017 school year were excluded from the research because their participation data in the Lexia intervention program was not available. The criteria for inclusion in the study was continuous enrollment in the district from the fall screening window in September to the spring screening window in May. Table 7 below shows the number of students who met the criteria for inclusion in the study by school year.

Table 7 Students Included in t Test Analysis by School Year

Year	n	Percent of total
2014	862	24.4%
2015	855	24.2%
2016	1006	28.5%
2018	809	22.9%
Total	3532	100%

The Washington School District provided data on students' reading growth from the students' Renaissance Star Reading Assessments. Using the IBM SPSS software program, outlier scores were identified. Scores that were three standard deviations either above or below the mean were removed from the data set. These 25 scores constituted less than one-percent of the total scores. The remaining scores were distributed along a normal curve as shown in Figure 8.

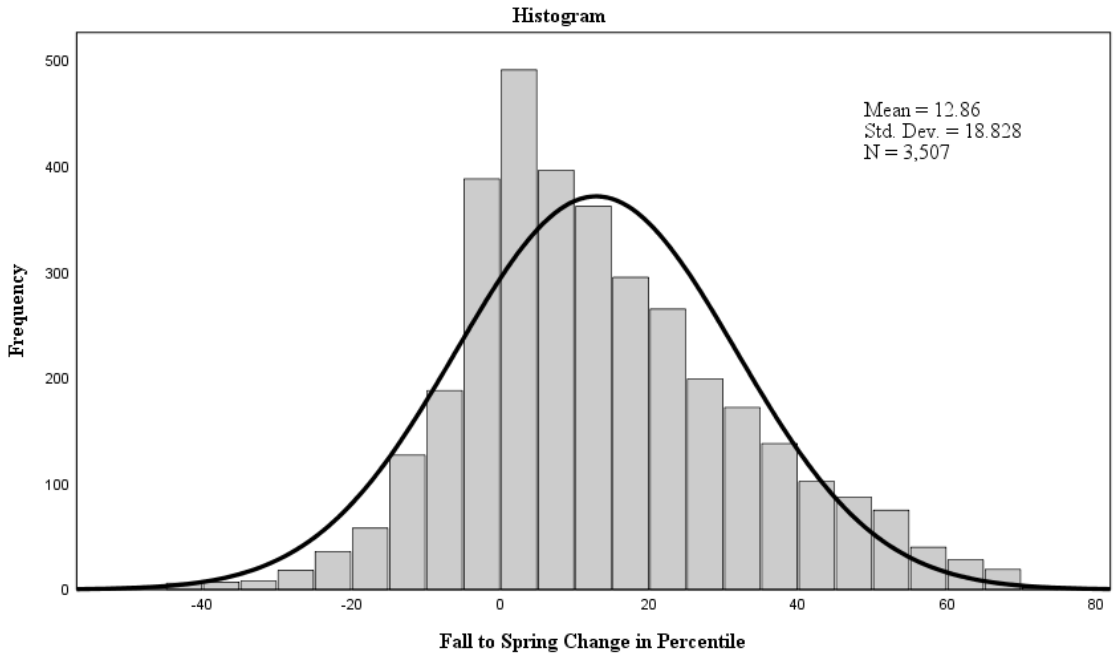

Figure 8. Distribution of Second-Grade Reading Percentile Gains

Test of Null Hypothesis 1

The first null hypothesis was that participation in the Lexia Core5 reading program would not have a significant impact on gains in student reading achievement. To test this null hypothesis, an independent samples t-test was conducted to compare the growth in percentile scores for two different groups: second-grade students who participated in Lexia for at least 30 hours in the 2017-2018 school year and second-grade students from 2014-2016 who never participated in Lexia. Pallant (2016) noted that independent-samples t-tests are appropriate measures to compare mean scores on a continuous variable for two different groups of participants. The results showed a significant difference in percentile gains between Lexia participants (M = 15.46, SD = 18.92) and non-participants (M = 12.09, SD = 18.73; t (3505) = 4.47, $p < .01$, two-tailed). The magnitude of the differences in the means (mean difference = 3.38, 95% CI: 1.90 to 4.86) was small (Cohen's d = .18). A series of five follow-up independent samples t-tests

were also conducted using randomly selected samples of 25% of the population as shown in Table 8. The results of these t-tests confirmed the results of the t-test of the entire population. The mean effect size for the follow-up t-tests was .28. From these results, the null hypothesis was rejected and the alternate hypothesis, participating in the Lexia Core5 program may influence student reading achievement, was accepted.

Table 8 Second-Grade Students' Gains in Reading Percentile from Fall to Spring

	Participants		*Non-participants*					
	M	*SD*	*M*	*SD*	*df*	*t*	*p*	*Cohen's d*
All	15.46	18.92	12.09	18.73	3505	4.47	<.01	0.18
Sample 1	16.87	20.30	11.96	19.41	881	3.13	<.01	0.25
Sample 2	17.16	17.60	12.22	19.10	877	3.22	<.01	0.27
Sample 3	16.47	17.77	10.57	18.30	880	4.15	<.01	0.33
Sample 4	17.61	20.20	11.57	18.44	33	3.82	<.01	0.31
Sample 5	16.47	18.72	12.35	18.78	868	2.67	<.01	0.22
Mean	16.92	18.92	11.73	18.81	767	3.40	<.01	0.28

RQ2. Key Factors that May Influence the Effect of the Lexia Intervention

Description of Population

The population for the second quantitative research question was comprised of students continuously enrolled in second-grade in the Washington School District from the fall screening window in September 2017 to the spring screening window in May 2018.

Key Factors

The purpose of the second research question was to identify key factors that may have had a significant effect on student reading gains. These key factors were organized into the following categories: (a) teacher variables, (b) classroom variables, (c) program variables, and (d) student variables.

Teacher Variables. The model included three teacher variables: (a) teacher years of experience, (b) teacher evaluation score, and (c) assigned classroom teacher, which as transformed into teacher mean reading gain. To account for the variation among students' assigned classroom teachers, the researcher transformed the assigned teacher categorical variable into an interval scale variable following the conduction of a preliminary one-way between groups analysis of variance. Analysis of variance tests are used to test the difference in means between more than two groups (Pallant, 2016). The predictor variable in the analysis of variance was assigned classroom teacher with students being grouped into 42 groups according to their assigned classroom teacher. The outcome variable was gains in percentile from fall to spring on the Star Reading assessment. The analysis of variance showed a statistically significant difference at the $p < .05$ level in percentile gains for the 42 teachers: $F (41, 774) = 2.1$, $p < .01$, as depicted in Table 9. The effect size, calculated using eta-squared, was 0.1, which is classified as a large effect size (Cohen, 1992). The researcher then transformed the assigned classroom teacher variable into an interval scale variable using the mean percentile gain score for the teacher's class.

Table 9 One-Way ANOVA Summary for the Effect of Assigned Classroom Teacher on Reading Gains

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	29969.269	41	730.958	2.110	<.01
Within Groups	268083.667	774	346.361		
Total	298052.936	815			

Classroom Variables. Two classroom predictor variables were selected for the multiple regression analysis: class size and Lexia implementation score. Class sizes ranged from seven to 27 students with a mean and median size of 21 students. Implementation scores were determined from teacher responses to a survey on how frequently they utilized features of the Lexia Core5 program. Teachers who scored high on implementation used all of the different elements frequently in their instruction while teachers who scored low rarely utilized the different elements of the Lexia program in their instruction. Responses were scored on a ratio scale from 0 to 5 points, and the implementation score variable was calculated by summing the total score for all of the responses. 23 of 40 teachers responded to the survey with a minimum implementation score of 7.8 and a maximum score of 100 with a mean score of 51.2 and median of 45.3 as shown in Table 10.

Program Variables. Two program variables were included in the analysis: the number of hours each student participated in the Lexia software and the number of levels each student completed. Lexia levels range from one to 17. Thirty-eight percent of second-grade students began at Level 10 and completed 5 levels in the software. The

mean and median hours students spent in Lexia was 40.7 and 40.5 respectively with a minimum of zero hours and a maximum of 123 hours as depicted in Table 10.

Student Variables. Four categorical variables that identified students' identification for an at-risk population were synthesized into a single scale variable: At-Risk Factors. This variable had a range from zero (no-at risk factors) to four (all four at-risk factors). The mean score for At-Risk factors was .78 and the median score was 1.0 as shown in Table 10.

Table 10 Descriptive Statistics for Predictor Variables in Reading Gains

	N	Min	Max	Mean	Std. Dev
Teacher Factors					
Mean Percentile Change	816	5.4	29.8	15.74	6.34
Years of Experience	816	1	29	12.10	9.69
Evaluation Score	816	56	100	87.49	12.01
Classroom Factors					
Program Implementation	410	7.8	100.0	51.22	26.92
Class Size	816	7	28	21.45	3.49
Program Factors					
Hours of Participation	807	1.0	123.0	40.72	18.99
Levels Completed	807	0	14	5.10	2.30
Student Factors					
Number of At-Risk Factors	816	0	4	0.78	0.92

Results

The model for the multiple regression analysis included the following key factors as predictor variables: (a) assigned teacher mean percentile gain, (b) assigned teacher evaluation score, (c) assigned teacher years of experience, (d) assigned teacher Lexia implementation score, (e) class size, (d) hours of participation in the Lexia program, (e) number of levels completed in the Lexia program, and (f) number of student's at-risk factors. Fall to spring gains in percentile on the Star Reading assessment was included as the criterion variable. Results showed that the model accounted for 12% of the variance in students' reading growth, $R^2 = .12$, $F(8, 398) = 6.7$, $p < .001$. This is a small effect size according to Cohen (Hatcher, 2013). Results of the regression are presented in Table 11. The only predictor variables that were shown to have statistically significant multiple regression coefficients were the teachers' class mean percentile growth and the number of hours students participated in the Lexia software program.

Table 11 Multiple Regression Summary of Predictor Variables for Reading Gains

Predictor variable	B	b*	t	p	95% CI	
Teacher mean percentile growth	.926	.307	5.575	.000	[.600	1.253]
Teacher years of experience	-.053	-.027	-.483	.629	[-.271	.164]
Teacher evaluation rating	-.024	-.015	-.306	.760	[-.178	.130]
Lexia level of implementation	.008	.011	.200	.842	[-.071	.087]
Class size	.075	.014	.258	.796	[-.498	.648]
Hours of participation in Lexia	.154	.153	2.481	.014	[.032	.275]
Lexia levels completed	-.133	-.016	-.259	.796	[-1.145	.879]
Number of at-risk factors	.220	.011	.221	.825	[-1.736	2.175]

These results indicated that the null hypothesis should be rejected; however, only two factors show statistical significance: teacher mean percentile growth and hours of participation in the Lexia program. Therefore, the alternate hypothesis was accepted with the following revision: The key factors of assigned classroom teacher and hours of participation in the Lexia program had a statistically significant influence on student reading gains while other key factors including teacher years of experience, evaluation rating, level of program implementation, class size, number of levels completed in Lexia, and student-at risk factors did not have a significant impact.

Qualitative Phase Results

This section describes the findings from the qualitative phase of the research project. In the explanatory sequential design of this mixed-methods research, the qualitative phase was designed to further explain the results of the quantitative analysis, specifically whether teachers who had exceptionally high effect sizes on reading gains shared common practices, perceptions, and beliefs.

Participant Demographics

Demographic characteristics of the participating teachers varied widely as shown in Table 12. Teaching experience ranged from one year to more than twenty years. Teacher ages also varied widely. Three of the teachers had regular teaching certificates, meaning that they had completed a university program for teacher certification while one teacher received an alternate authorization meaning that she completed a nontraditional route to certification.

Table 12 Demographics of Teachers Purposefully Sampled for Interviews

Pseudonym	Apple	Berry	Cherry	Lemmon
Gender	F	F	F	F
Age	59	29	66	51
Teaching experience	2	7	21	1
Certification	Regular	Regular	Regular	Alternate

Transcripts of each interview were initially coded using "process coding" (Charmaz, 2014; Saldaña, 2016). Following the initial coding, two other methods were incorporated into the analysis: magnitude coding and subcoding.

Identified Themes

After individual passages were coded, codes were organized to identify thematic connections (Seidman, 2013). Through this process, the following beliefs and practices were identified as common among the participants: (a) teachers provided differentiated levels of reading instruction based on students' reading achievement scores in the fall, (b) most teachers worked in collaborative teams to provide targeted interventions for students, (c) teachers used the Lexia software program to monitor learning, but also provided more intensive interventions as necessary, (d) teachers used classroom recognition to motivate students' learning, and (e) teachers demonstrated positive attitudes toward learning to integrate technology into their instruction tempered by cautious and conservative views of how large of a role technology should have in their classrooms.

Differentiated Instruction. All teachers described using Lexia to provide differentiated reading instruction and intervention to students. Charmaz (2014) noted that

"when researchers study a process, their coding categories will reflect the phases of the process (p. 80). Saldana (2016) suggested graphically representing these phases as a flow diagram. Figure 12 depicts the phases described by teacher to provide targeted instructional support and intervention for all students in their classroom.

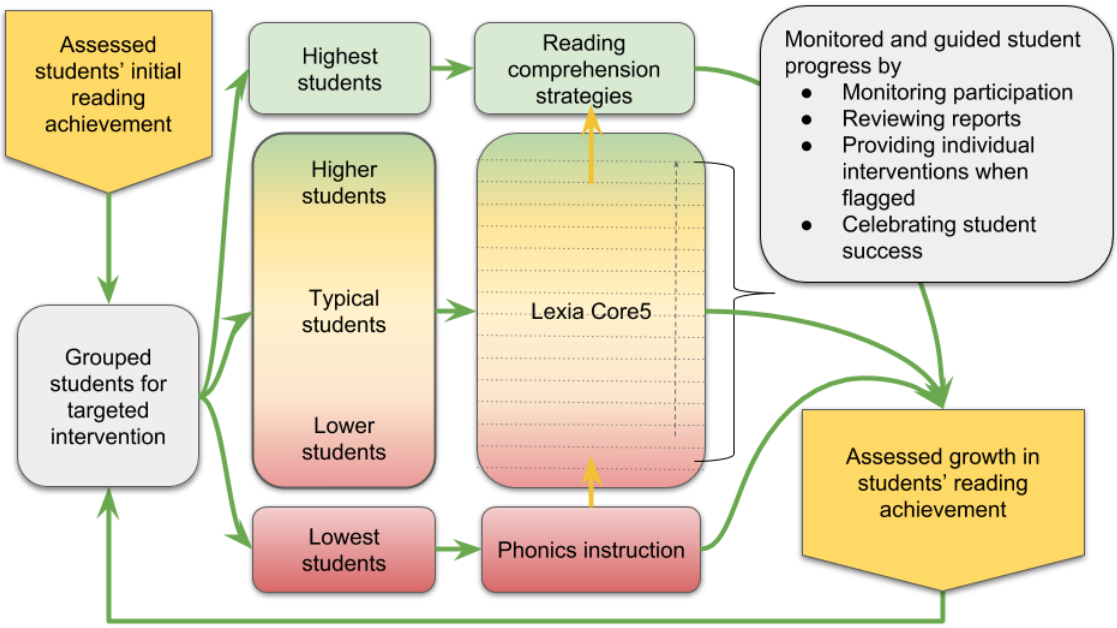

Figure 9. Process of Providing Targeted Intervention

Teachers described using diagnostic assessments to identify students' current level of reading achievement. All teachers stated that they use the Star Reading Assessment and the Idaho Reading Indicator as diagnostic assessments to evaluate students' reading skills and to assign students to flexible groups for targeted intervention. Teachers described grouping students into low, medium, and sometimes high groups for targeted intervention. Both the IRI and the Star Reading assessments provide teachers with reports using similar groupings: below basic, basic, and proficient or urgent intervention, intervention, on watch, and advanced, respectively. Teachers described a

fluid process to these groupings, moving students to different interventions as their reading achievement grew, stating for example, as Ms. Berry did: “Everything is fluid based on student need.” Most of the teachers reported that approximately half of their students were identified as at-risk readers on the fall assessment and required Tier Two reading support and interventions.

Ms. Berry attributed the growth of her students to her grade-level team’s intervention groups: “I attribute the scores and the strengths of my class really to being able to target those skills and break kids into small groups and meet those needs.” Teachers typically provided 30 to 60 minutes of literacy intervention time each day. Within this process, all teachers described using Lexia to address students whose reading skills ranged from low to high. All of the teachers described using more intensive interventions for the lowest students and some of the teachers also described using more extensive learning opportunities for the highest students.

Using Lexia for reading intervention. All of the teachers used Lexia Core5 as the primary reading intervention for students in the medium and high groupings. Teachers expressed confidence in Lexia Core5 to deliver appropriate and effective instruction to students. For example, Ms. Cherry noted that “Lexia instructs the children using proper terms such as closed vowel, open vowel, or control vowel. It teaches skills in depth.” Ms. Apple stated, “Lexia has a good component in breaking down word parts so that students can actually see how the words are put together, exactly what makes those sounds and how that translates into written language.” Students typically worked independently in the software program with a teacher or paraprofessional monitoring their progress. With a few key exceptions, the teachers’ involvement for this group of students was minimal as

the students were able to progress through the different levels of the program independently.

One key theme shared among teachers was that for on-target students, Lexia reinforced their own reading instruction. As stated by Ms. Cherry, "Lexia reinforced everything I was teaching them, phonics, and spelling rules, and the general rules of learning to read our language. Or, if students were ahead in Lexia, then when I would teach those skills to the whole class, they would often raise their hand and say, 'Oh I learned that in Lexia!' It was like double learning was going on." Teachers also described the effectiveness of Lexia's mastery-based instructional design that provides adaptive instruction targeted to students' current reading level with immediate feedback on their progress. Ms. Berry described this design in these words:

> One really important aspect of Lexia is that it provides students with immediate feedback. The thing about reading is that it needs to be perfect practice. Students need to have feedback about their errors and not just continue to make mistakes or they are not going to grow. When kids make errors in Lexia, the software addresses their misunderstandings. And if students do not correct their errors, it kicks the apple icon to show that they need direct instruction and we can intervene so that they are not mispracticing [sic].

Intervention for low students. For the lowest group of students, all of the teachers took a much more active role providing one-on-one instruction with a primary focus on developing students' phonics skills. In addition to students working in Lexia, teachers also described working with students individually or in small groups to develop foundational reading skills, especially in phonics. Ms. Berry explained,

> Sometimes, those low students do not grow with Lexia because they are making reading errors in their head . . . so we sit at a table with groups of only six or seven students and progress through short vowel sounds, long vowel sounds, digraphs, and vowel pairs. This helps students with lower reading skills because it requires them to read aloud. When students read aloud in the phonics groups, I start to regulate and the errors that students are making in their heads and can pinpoint what they need.

Other teachers worked individually with students to target individual specific skills. Ms. Apple stated that she worked with students individually because they were all at different levels and did not all have the same struggles. Several teachers expressed the critical importance of the Lexia software program to enable them to provide this individual instruction. For example, Ms. Cherry stated:

> I know differentiation is important but every day to get a differentiation group going and to be able to work with these kids is almost impossible timewise for a teacher to be able to manage. To be able to have everyone engaged on the computer gave me time to work with individual students that I haven't had in the past. I used that time when my students were engaged on the computer Lexia to pull those low students over to my desk where I could work with them individually.

Enhanced learning for high students. Lexia Core5 provides instruction on reading skills up to the 5th grade level which most teachers felt addressed the needs of the high group of students. In most of the classes, students did not complete all of the levels during their second-grade year. Ms. Berry, however, also described using Motivation

Reading to continue to enhance reading development for students who completed all of the levels in Lexia. This program provided students with fiction and nonfiction reading passages along with comprehension questions. Ms. Berry also explained:

> If students score really high on the Star Assessment at the beginning of the year and if they do not show growth after the first two screening windows, we will just move them out of Lexia and into Reading Motivation because Lexia is not improving their academic performance. That's very few kids. We want to make sure we fill students' learning gaps, so we make sure they participate in Lexia first. But if the results do not show that the intervention is meeting their needs, then we move them into a different intervention.

Working in Collaborative Teams. Most of the teachers described the impact of collaborative teamwork where they work closely as a grade-level team to create flexible groups with targeted interventions for each group. Ms. Berry explained:

> I really attribute our grade-level intervention groups to our academic achievement. It's a lot easier to target instruction and groups as a team and share kids than it is in isolation. I wouldn't be available to sit down with a group of six kids in my own classroom if I didn't have those extra hands--those paraprofessionals and extra teachers all helping each other out. And it's not just my kids, you know, it's all of our kids.

This sentiment was shared by the other teachers as well, including Ms. Cherry who was not able to work in a collaborative team to provide intervention to students:

> This year we didn't have Special Ed, or Title 1 or computer-lab time so we just 'RTI'd' our own kids in our own classrooms. We found ourselves working our

> tails off trying to provide for every child's needs. Unless Lexia or MobyMax provided extra help, we were not meeting their needs hardly at all.

Teachers who did work in collaborative teams underscored the effectiveness of a team-based approach to providing intervention. Mrs. Apple noted, "My team works really, really well. All of us can be better than we can be by ourselves." Teachers described working together to be able to provide small group and individual intervention for the students with the highest needs while a teacher and a paraprofessional worked with students in the Lexia program. As collaborative teams, teachers typically described meeting together on at least a weekly basis to review reports from Lexia as well as the diagnostic assessments and to identify target areas for additional instruction.

Using Lexia Core5 to Monitor Student Progress. Participating teachers described actively monitoring student progress in Lexia in two ways: (a) monitoring intervention flags, and (b) reviewing progress reports on a weekly basis.

Monitoring intervention flags. Teachers described actively monitoring students while they are participating in the Lexia Core5 program. Mrs. Apple noted, "I don't just sit here and let them use Lexia. I am constantly monitoring to make sure they were doing okay with it." When students branch to the Instruction Step more than once, an apple icon in the lower-left side of the screen turns red indicating to the teacher that the student is flagged as needing direct instruction with a recommended Lexia Lesson (Lexia Learning Systems, LLC, 2017, p. 5). Ms. Lemmon described her process in monitoring students' progress in these words: "I would walk around while students were doing Lexia. There were lots of questions and red apples. When students received intervention flags, I would sit with them and say, 'Okay. We need to go back. How do you do this?' And then we

would do a couple of questions together and then I would have them do it by themselves. That helped get them back on track." Teachers also described using their professional judgment with the intervention flags. For example, Ms. Berry stated:

> Sometimes Lexia will kick needing instruction a little bit too early and students just need to work on that skill a little bit longer. You have to be careful to not do it too early; otherwise, they really have this error because they have been introduced to a new concept and just need a little bit more practice with it. But, any time I see a medium or high priority intervention flag, I pull instruction immediately to make sure I have that instruction time with them.

This approach was shared by other teachers during their interviews as well. For example, Ms. Apple explained, "Usually the low and the medium strugglers work it out on their own and I work with the high strugglers because I just don't have time to print up ten extra Lexia lessons."

Reviewing progress reports. All of the teachers also described regularly reviewing intervention reports, usually at least on a weekly basis. Teachers described using the reports to better understand where each of their assigned students are skill by skill. As Ms. Cherry explained, "The reports guide me in knowing who is struggling and remind me which specific skills students may still be missing." Ms. Berry explained that in the RTI process, where students are shared among different classrooms, these reports help teachers to know how their own students are performing, even when they are not directly instructing them.

Using Classroom Recognition to Motivate Students. Teachers also described how the successive achievement levels and recognition help to motivate students' efforts to

learn. Teachers described two key ways that the program helps to motivate learning efforts. First, the successive achievement levels provide a sense of accomplishment and sometimes competition for students. Ms. Berry stated, "I think students like to see their own growth. I will say, 'You know you started at Level 12, and look at you, you're at Level 17!' and they can see for their progress for themselves. I think that's super motivating to them." Ms. Cherry described how she mentioned that two students from another class had completed the program, inadvertently motivating several students in her own class to strive to complete the program. "[Their] eyes got big and they said, 'I think we could do it!' They did not get a grand prize for finishing it. It was purely they wanted to do it." Second, all of the teachers described celebrating students' achievement by recognizing students' accomplishments. The Lexia program provides certificates that teachers print as students pass off each level. All of the teachers described doing celebrations where they would present these certificates to students in front of the whole class. Ms. Lemmon stated, "Students loved to get the printed certificates. The thing that I loved about this class is that when someone would get a certificate, they would clap. It didn't matter what level they were on or who it was, they would clap. This class was very supportive of each other. Because of that, everyone liked to get the certificates." Ms. Berry expressed that these celebrations were more effective than providing trinkets or tokens to students: "That acknowledgment is so much more valuable and motivating than the Treasure Box or anything else in the classroom. That certificate is more meaningful than anything extrinsic."

Demonstrating a Positive but Cautious Attitude toward Technology Integration. Finally, all teachers expressed positive attitudes toward integrating technology into their

instruction, but also expressed that instructional technology should play a limited supporting role to typical face to face instruction.

Learning to use technology. The interviewed teachers described learning to use the Lexia software program by simply "jumping in and exploring" it. Most of the teachers stated that they participated in an initial webinar to get started with the program, but then learned the program through trial and error. Ms. Apple described her learning process this way: "I just started using it and deciding what helped me the most to identify where the kids have holes." This idea of learning the program by doing it was common among all of the interviewed teachers.

Cautious technology integration. While each teacher expressed a positive view of the role of technology in their instruction, she also expressed concern about its overuse. Ms. Apple stated, "I try to not to use [instructional technology] more than half an hour a day because I feel like teacher instruction and student engagement is a better way to learn than technology." Ms. Berry teacher expressed her reservations about the use of technology: "Sometimes teachers misuse Lexia as more of a babysitter and [do] not manage it properly. But I think if it is managed properly and used it to its fullest potential, then it's really valuable." At the same time, the interviewed teachers discussed benefits of using instructional technology in instruction, including facilitating differentiated instruction and engaging students. Ms. Berry shared an anecdote of a student who had already mastered multiplication before she had introduced foundational concepts to the rest of the class:

> But she still needs to be able to progress just like every other kid. And if I didn't have a program and a Chromebook with access to things like Khan Academy or

> Google Forms or these games online, then I would have to that all manually. These instructional technology tools allows me to be able to give her instruction and a private lesson that I wouldn't have time for otherwise.

Ms. Cherry shared an anecdote of another student who "was very attention deficit and has an extremely hard time focusing. But she was able to focus on the computer screen [with Lexia] because it kept her so engaged." Ms. Apple succinctly summed up all of the teachers' sentiments noting that while instructional technology has an important role in her classroom, "Computers just don't love them the way I do."

Qualitative Findings

The qualitative phase of the research project was designed to learn whether teachers with high effect sizes on reading gains share common practices, perceptions, or beliefs. Through semi-structured interviews, it was learned that first, teachers with high effect sizes on reading gains used the Lexia software program to provide tiered levels of instruction and intervention to students. Teachers used the software to provide instruction to students who were at, above, or slightly below grade level, but also provided one-on-one instruction to students at the lowest reading levels. Second, teachers typically worked in collaborative teams with other grade-level teachers or paraprofessionals to provide differentiated instruction, typically describing this approach as RTI or Response to Intervention. Third, teachers publicly celebrated students' achievement as they achieved each level in the software, which they described as motivating students' achievement. Finally, teachers expressed a positive attitude toward "jumping in and learning" to use the program, but also cautioned against an over-reliance on technology instead of teacher instruction.

Mixed Methods Results

The overall purpose of the research design was to determine how teachers may influence the impact of computer assisted instruction on student learning. In the quantitative phase, it was learned that participating in the Lexia Core5 reading program did have a significant effect on students' reading gains. It was also determined that among many potential factors influencing student reading gains, including student at-risk status, assigned classroom teacher, number of hours of participation in the Lexia program, teacher experience, teacher evaluation score, class size, and level of implementation of the Lexia program, only the students' assigned classroom teacher and the number of hours of participation in the Lexia program were significant. The students' assigned classroom teacher had the largest influence on reading gains; therefore, understanding what practices, beliefs, and perceptions those teachers with high effects on reading gains have became crucial. Through interviews with those teachers, it was learned that these teachers focused on differentiated instruction, citing the importance of the Lexia program to meet the needs of most students and affording them the opportunity to work individually with the most at-risk students. Teachers also typically worked in grade-level teams to provide instruction in flexible groupings of students, a model known as Response to Intervention or RTI. Teachers also recognized and rewarded students' achievement by publicly celebrating their accomplishment as they completed each level of the program. And finally, all of the teachers expressed a positive but cautious attitude toward instructional technology. These shared beliefs and practices may explain how students in these teachers' classes grew significantly more in their reading achievement than their peers in other classrooms.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

Summary of Findings

Attaining grade-level reading literacy for all schoolchildren has been a major goal of national and state school improvement efforts for decades (Chall, 1983; Committee on the Prevention of Reading Difficulties in Young Children, 1998; NRP, 2000b). In Idaho, this focus had led to the adoption of new legislation designed to improve reading literacy statewide (Idaho Legislature, 2016). National and state mandates have led districts in Idaho and across the nation to adopt computer adaptive instructional programs designed to provide individualized reading instruction and intervention; however, critics have expressed concern that such programs lack empirical research supporting their efficacy (Gibson et al., 2011). For the past three decades, meta-analyses have shown computer adaptive instructional software to have a small, but statistically significant effect size (Cheung & Slavin, 2013; Hall et al., 2000; Soe et al., 2000; Tillman, 2010).

While large-scale meta-analyses provide an overall idea of how computer adaptive instruction typically influences learning outcomes, they do not provide much insight into the variability within the summarized studies. Some research of the effect of CAI has shown it to have no significant effect, some research has shown it to have a much higher effect size, and some research has even shown it to have a negative influence on reading gains (Khan & Gorard, 2012; Shannon et al., 2015). The purpose of this research design was to first identify whether participation in the Lexia Core5 reading

program as a specific instance of CAI had an effect on student reading gains, and second to understand what key factors may influence that effect size.

To learn whether participation in Lexia had a significant effect on students' reading achievement, the researcher compared the mean percentile gain from fall to spring on the Star Reading test between two groups: second-grade students from 2013-2016 who had never participated in the Lexia program and second-grade students from the 2016-2017 school year who participated in Lexia for a minimum of 30 hours. The results showed that students who did participate in Lexia gained an average of three more percentile points than students who never participated in the program. This difference was found to be statistically significant, but with a relatively small effect size of .18.

To learn what key factors may influence the gains in reading achievement, the researcher first analyzed a number of potential variables, which were grouped into the categories:

- teacher variables: assigned teacher's years of experience, evaluation score, and class mean growth score,
- classroom variables: class size and fidelity of the Lexia implementation
- program variables: number of hours of participation in the Lexia program and number of levels completed in the program,
- student at-risk factors: minority status and inclusion in special education, English as a secondary language, or free and reduced lunch programs.

Of these factors, only the teacher's mean growth score and students' hours of participation in the Lexia program were found to be statistically significant influences on reading gains. The researcher then selectively sampled those teachers whose classes

significantly outgained their peers in reading growth for a follow-up interview. The researcher coded statements from each teacher using action verbs to identify the processes and actions that teachers identified as key factors in their instruction. Identified key factors included providing differentiated instruction to students, working in collaborative teams, celebrating student success, and having a positive but cautious approach to technology integration.

Interpretation of Findings

Quantitative Phase

The results from the first research question converged with the results of the metanalyses reviewed in Chapter 2. Table 13 below shows that previous studies of Lexia Core5 have typically found moderate effect sizes with effect sizes ranging between .06 and .69. However, these studies usually targeted a particular subset of the population such as English Language Learners or a lower grade level than this research study. The analysis in the first research question found the effect size for participating in Lexia to align closely with metanalyses of the effect of computer-adaptive instruction on reading achievement, which have typically found statistically significant results with small to medium effect sizes (Cheung & Slavin, 2013; Hall et al., 2000; Soe et al., 2000; Tillman, 2010).

Table 13 Effect Sizes of Studies of the Lexia Reading Intervention

Authors	Grade	Group	Test	Effect	Classification
Macaruso & Rodman, 2011b	Pre-K	all		+0.69	Moderate
Macaruso & Walker, 2008		all	ANCOVA	+0.48/+0.53	Moderate
O'Callaghan et al. 2016	K	all	ANCOVA	+.06 / +.07	Small

Schechter et al. 2015	1st/2nd	ELL	t-test	.53	Moderate

Findings from the second research question, however, were more surprising. Traditionally, a number of the key factors that were included in this analysis have been considered to have a significant effect on reading achievement, particularly student at-risk factors, teacher evaluation scores, and class size. However, none of these factors were found to have a significant influence on student reading gains. One key reason why these factors may not have had significant influences is that the research design focused on gains in student reading achievement instead of instead of focusing on achievement scores. Achievement scores typically have high correlations to student at-risk factors, but this correlation often disappears when growth scores are used instead.

The other surprising outcome was related to the teacher variable. A preliminary analysis of student reading gains showed that the students' assigned classroom teacher had a high effect size of 0.1. This aligns with findings from prominent researchers in education including Robert Marzano (2007), who wrote "the single most influential component of an effective school is the individual teachers within that school" (p. 1). In a frequently cited study, Nye, Konstantopoulos, and Hedges found that teacher effectiveness accounted for about one-third of a standard deviation in student reading outcomes (2004). While research has consistently demonstrated the impact of effective teachers, identifying the key factors that make teachers effective is much more difficult. An exhaustive study of these potential factors is beyond the scope of this research project; however, it has been a significant area of research for many prominent researchers including John Hattie and Robert Marzano (Dean & Marzano, 2012; Hattie,

2012; Marzano, 2007). In this research design, several key teacher variables including their evaluation score and years of teaching experience were not found to be significant; therefore, other key variables about individual teachers must contribute to the statistical significance of students' assigned classroom teachers.

Another surprising finding was that teachers' fidelity of implementation of the reading intervention program was also not statistically significant. As noted in Chapter Two, Archer et al. (2014) theorized that fidelity of implementation may have a significant impact on results especially when the regular classroom teacher is responsible for implementing the intervention. In this research project, teacher implementation scores were derived from their responses to survey questions on how regularly they implemented various aspects of the program and how much training they have participated in. The research did not show, however, a significant correlation between the teacher's implementation score and gains in student reading scores.

Another surprising finding was that while the number of hours that students participated in the program had a significant correlation to their reading gains, the number of levels they completed did not. The simplest explanation may be that progressing through the successive levels may not be as important as students' learning to master foundational skills before progressing to the next skill. There is an oft-quoted adage that if time is the constant, learning becomes the variable, but if learning is the constant, then time becomes the variable. Rather than moving onto new content according to a predetermined schedule, as traditionally has happened in American classrooms, students remain at their current level until they are able to demonstrate sufficient mastery of its skills and content.

Qualitative Phase

Findings from the qualitative phase also presented some expected and some unexpected results. First, teachers all described approaching literacy instruction by organizing students into different groups based on results from the fall reading assessment. All of the teachers described using the Lexia program to provide differentiated reading instruction to students, which was expected. The unexpected finding was that teachers also described how the Lexia program allowed them to work individually with the highest needs students while the rest of the class was engaged in the Lexia program. As Mrs. Cherry explained, "To get a differentiation group going every day is almost impossible timewise for a teacher to be able to manage. So to be able to have everyone engaged on the computer to work one-on-one with students is an amazing tool for me." All of the interviewed teachers identified this as a key advantage of having access to computer adaptive instruction in their classroom.

Another unexpected result from the qualitative phase was the shared practice of celebrating student success in the program as a class. The Lexia software program provides teachers with printable certificates to celebrate students' success in completing each level in the program. Instead of simply printing the certificates for students, each of the teachers described publicly celebrating the students' success in their classroom. As described, the celebrations were typically low-key. For example, Mrs. Berry used the phrase "Give your classmates a quiet celebration" and demonstrated "golf claps" that students would give. While such celebrations are not promoted in the Lexia teacher manual, all of the teachers described the motivational influence these celebrations had on students.

Finally, the teachers' similarity in attitudes toward instructional technology was also somewhat unexpected. Even though, the ages of the teachers varied significantly from early 30s to mid-60s, they all had positive attitudes toward instructional technology and the Lexia program. It was surprising to learn that none of the teachers described participating in extensive training for the Lexia program, instead commonly describing learning the program by simply "jumping in and trying it." Often a lack of training may be a sore point for teachers who are implementing a new software program, but none of the teachers described hands-on learning negatively. However, the teachers were cautious in describing the importance of technology in their instruction, commonly recognizing its value to them in supporting their instruction, while at the same time arguing that technology cannot replace effective instruction. As Mrs. Berry stated, technology should not be used "as a babysitter" for students.

Implications of Findings

Methodological Implications

Results from the mixed methods research design underscore the importance of integrating quantitative and qualitative methods to evaluate the effect of instructional technology on learning. A strictly qualitative study would not adequately address the need of the district to know whether the reading intervention that had been purchased and pushed into classrooms was having the desired effect of improving student reading outcomes. At the same time, a strictly quantitative analysis would fail to provide a comprehensive understanding of the impact of the software on reading instruction. A strictly quantitative analysis would also fail to illuminate the key practices that influence the effectiveness of the intervention. For example, the unexpected result of Lexia

providing teachers with one-on-one instructional time with the lowest students would have been missed in a strictly quantitative study. As Friesen (2009) argued:

> Practices of these kinds are not always anticipated in the technical design and improvement of ICTs in learning, and do not always occur right at or directly through a technological interface. . . research consequently also needs to focus on what students and teachers are actually doing with technology in often complex circumstances and how they may be adapting it in unforeseen ways to their own educational practices and priorities. These obvious but complex questions are all too easily overlooked . . .” (p. 9).

Applied Implications

The results from this research study provide a number of different implications for various education stakeholders. First, for the leadership of the Washington School District, the results show that the Lexia software program has a statistically significant effect on student reading gains. This result should provide some measure of assurance that the investment of time and money in the program has resulted in the desired benefits. Further, the research shows that even with the same intervention program, some teachers are seeing significantly higher gains in reading than their peers. These classrooms can serve as “bright-spots” of best practices to be identified and shared with other teachers throughout the district (Heath & Heath, 2010). Further, the explanatory evidence from the qualitative research will guide professional development decisions to improve the implementation in the CAI across classrooms to increase the efficacy of the program and improve learning results for students.

The research also provides implications for classroom teachers. Specifically, the teachers with the highest learning gains all identified Lexia as one key component of their instruction, but not the only component. If teachers have been reluctant to implement the Lexia software in their classrooms, it should serve as some assurance that students with more participation time in the program demonstrated significantly higher reading gains than students with less participation time. Another implication is that the lowest students may need more intensive, one-on-one intervention, especially in phonics, before they are able to successfully progress in the Lexia program. All of the teachers described providing individualized phonics instruction to students with the lowest reading achievement in the fall. Using instructional time afforded by the Lexia program to provide more intensive intervention to these students may be the key to remediating the gaps in their foundational reading skills. Teachers should also recognize the importance of publicly celebrating students' success in the program. While none of the teachers went so far as to use visible tracking systems in their classrooms to show students' progress, they did all describe creating opportunities to publicly recognize and celebrate students as they passed off each level in the program. Finally, adopting a "can-do" attitude in integrating the Lexia program into their instruction may also influence its effectiveness in their instruction.

On a larger scale, this research supports and contributes to the existing literature on the efficacy of computer-adaptive instruction for reading and specifically, the Lexia Core5 reading program. Computer-adaptive instruction continues to show demonstrable effects on student reading outcomes; however, highly effective teachers continue to have a much more powerful effect. The implication from this is to first focus on the

instructional effectiveness of teachers, then technology can support teachers in delivering instruction by enabling them to focus more time and effort on the students who are at the highest risk for reading failure.

Limitations of Study

Internal and External Validity Issues

There are several internal and external validity issues involved with this research. First, the researcher is a senior administrator in the district with key responsibilities for the district's continuous improvement plan. The Lexia program is a key strategy of the district's early literacy goals. This level of involvement may create the appearance of bias in the researcher to show promising results for the district's key strategies. Further, the researcher's position within the district may have caused teachers to be less than candid about their experiences with the Lexia software program or the instruction in their classrooms. Because the selected teachers all showed high learning gains, this issue was likely minimal and would be of larger concern if teachers with lower than average results had been selected. Furthermore, all interviews were digitally recorded. These recordings provide a record of the interviews that may be reviewed and audited for potential bias.

Measurement and Statistical Issues.

In addition to the internal and external validity issues, there are also potential limitations with the methods in the study. For example, in the first research question, there was no random assignment of students to test and control groups. Furthermore, there could be a number of variables besides the adoption of the Lexia software program that contributed to the difference in reading gains between the two groups. Therefore, these results should only be considered as correlational and not causative.

Recommendations for Further Action and Research

In the first phase of the research design, only scores from second-grade students were included in the analysis. To get a broader understanding of the impact of Lexia on early literacy gains, scores from kindergarten, first-grade, and third-grade students should be evaluated as well. Furthermore, scores from subsequent school years should also be analyzed to ensure the results consistently show the same reading gains.

Also, in the second research question, a number of factors that were presumed to have a possible influence on student reading gains were included in the analysis; however, there are likely other influences that the researcher did not identify for inclusion. Investigations into other potential factors influencing reading gains may contribute to the overall understanding of what influences students' growth in reading ability.

Finally, in the third research question, common practices, beliefs, and perceptions of teachers with significantly higher reading gains were identified. However, it is not known whether teachers with typical reading gains or significantly lower reading gains also shared these beliefs, practices and perceptions. To better understand the significance of these factors, interviewing teachers with typical reading gains and low reading gains would provide deeper insight into how meaningful the results from this phase of the research are. For example, if all teachers—regardless of reading gains—shared the same practices about differentiating instruction, then further research would be necessary to identify where, if anywhere, the differences lie.

Another important perspective missing from the current research design is the students' perspective on learning from the Lexia software program. Listening to students'

voices about instructional programs, especially computer programs, could provide valuable insight as to how such programs may engage students in learning, how motivated they feel by the program, and what their perceptions are of learning from a computer compared with learning from a teacher.

Summary

The era of school accountability that dawned with the *No Child Left Behind* Act of 2002 coincided with a surge in the integration of instructional computers with Internet connectivity into classrooms as shown in Figure 10 below. In response to federal and state mandates for accountability and with the advent of web-based instructional applications, school districts have invested heavily in instructional technology to improve student outcomes leading to a burgeoning multibillion-dollar educational technology industry.

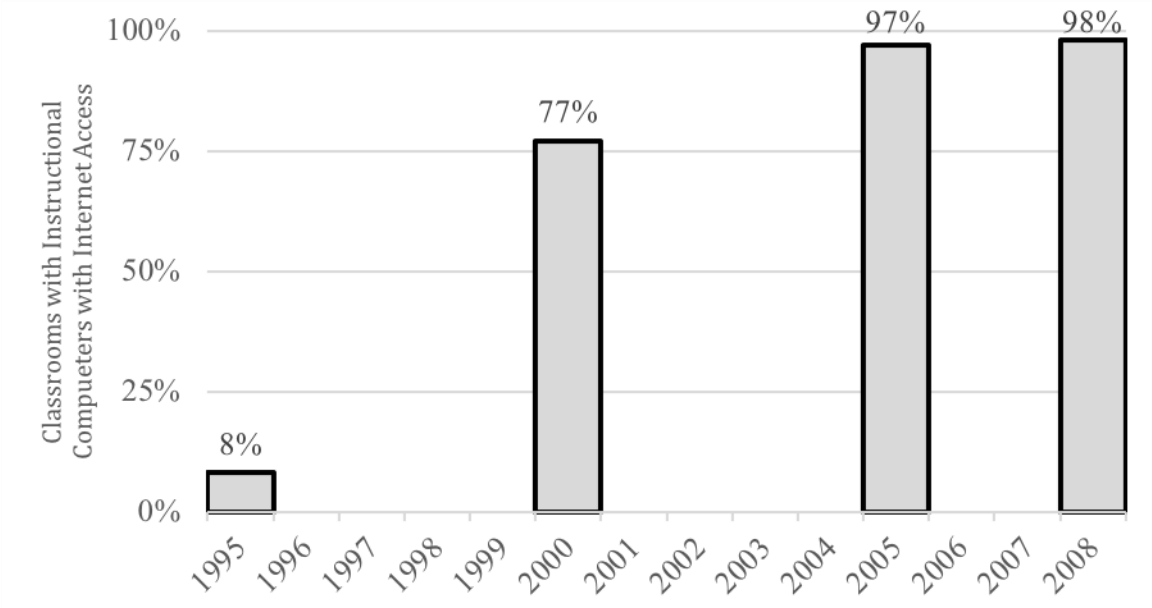

Figure 10. U.S. Classrooms with Instructional Computers with Internet Access

Data from U.S. Department of Education, National Center for Education Statistics, Fast Response Survey System (FRSS). (2010). *Internet Access in U.S. Public Schools and Classrooms: 1994-2005 and Educational Technology in U.S. Public Schools: Fall 2008; and unpublished tabulations*. Used with permission.

The purpose of this research was to show whether instructional technology can deliver on its promise to increase student reading outcomes and to identify how the classroom practices and beliefs of teachers may influence those results. The research found that instructional technology can have a positive effect on student gains in reading; however, districts should have realistic expectations of relatively small effect sizes for instructional technology. Teachers who achieved significantly higher reading gains described using technology as leverage to increase their effectiveness in providing targeted reading instruction and intervention for all learners in their classroom. The Greek mathematician Archimedes is credited with the statement, “Give me a place to stand and with a lever I will move the whole world” (“Archimedes - Wikiquote,” 2018). With effective classroom instruction as their foundation on which to stand, instructional technology may prove to be the lever with which teachers can move the world, achieving the promise of every child learning to read.

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APPENDIX A

Star Reading Core Progress of Skills

Table 3: Core Progress for Reading: Domains and Skills

Domain	Skill Set	Skill
Word Knowledge and Skills	Vocabulary Strategies	• Use context clues • Use structural analysis
	Vocabulary Knowledge	• Recognize and understand synonyms • Recognize and understand homonyms and multi-meaning words • Recognize connotation and denotation • Understand idioms • Understand analogies
Comprehension Strategies and Constructing Meaning	Reading Process Skills	• Make predictions • Identify author's purpose • Identify and understand text features • Recognize an accurate summary of text
	Constructing Meaning	• Understand vocabulary in context • Draw conclusions • Identify and understand main ideas • Identify details • Extend meaning and form generalizations • Identify and differentiate fact and opinion
	Organizational Structure	• Identify organizational structure • Understand cause and effect • Understand comparison and contrast • Identify and understand sequence
Analyzing Literary Text	Literary Elements	• Identify and understand elements of plot • Identify and understand setting • Identify characters and understand characterization • Identify and understand theme • Identify the narrator and point of view
	Genre Characteristics	• Identify fiction and nonfiction, reality and fantasy • Identify and understand characteristics of genres
Understanding Author's Craft	Author's Choices	• Understand figurative language • Understand literary devices • Identify sensory detail
Analyzing Argument and Evaluating Text	Analysis	• Identify bias and analyze text for logical fallacies • Identify and understand persuasion
	Evaluation	• Evaluate reasoning and support • Evaluate credibility

APPENDIX B

Qualitative Interview Protocol

Q1. Why do you think students have had higher-than expected reading achievement in your classroom this year?

Q2. Tell me about the role that technology plays in your instruction.

Q3. What are your thoughts about the Lexia reading program?

Q4. What do you typically do while students are using Lexia in your classroom?

Q5. How have you learned to do Lexia in your classroom?

APPENDIX C

Letters of Approval for Research Study

January 23, 2018

Dear Boise State Institutional Review Board:

On behalf of the [redacted] School District Leadership Team, which is responsible for approving proposed research projects in our school district, I approve the research project that Scott Woolstenhulme has proposed for his dissertation.

This project will provide the district with key results on the effectiveness of our literacy intervention program and will help to inform our decision on how to best provide intervention for struggling readers. This research also falls within the normal scope of responsibilities assigned to [redacted] and presents no additional risk to our students than is typical of any analysis of results of programs and interventions in our district.

If you have further questions, please feel free to contact me at [redacted] or by email at [redacted].

Sincerely,

[redacted]

Deputy Superintendent

[redacted]

[redacted]

January 23, 2018

Dear Boise State Institutional Review Board:

As the Director of Instruction and Learning, I endorse the research project that Scott Woolstenhulme has proposed for his dissertation.

As the Director of Instruction and Learning, I am responsible for the District Literacy Intervention Plan. The proposed project will provide us with key information to understand the impact of our literacy intervention plan and to identify potential areas of success. As a district, we must make a decision this summer whether to continue providing this particular intervention for students. This project will help to inform that decision.

If you have further questions, please feel free to contact me at [redacted] or by email at [redacted]

Sincerely,

[redacted]

Director of Instruction and Learning
Bonneville Joint School District 93

[redacted]

APPENDIX D

Form Letters for Informed Consent

Lexia Implementation

INFORMED CONSENT
Study Title: How Do Teachers Influence the Impact of Computer Adaptive Instruction?
Principal Investigator: Scott G Woolstenhulme
Co-Investigator: Dr. Ross Perkins
Sponsor: Bonneville Joint School District 93

This consent form will give you the information you will need to understand why this research study is being done and why you are being invited to participate. It will also describe what you will need to do to participate as well as any known risks, inconveniences or discomforts that you may have while participating. We encourage you to ask questions at any time. If you decide to participate, you will be asked to sign this form and it will be a record of your agreement to participate. You will be given a copy of this form to keep.

PURPOSE AND BACKGROUND
The purpose of this research is to examine how teachers may influence the effect of computer adaptive instruction, specifically the Lexia Core5 reading program, on student growth in reading.

You are being asked to participate because you are second grade teacher in Bonneville School District in the 2017-2018 school year.

PROCEDURES
If you agree to be in this study, you will participate in one 5-minute survey about how you have implemented Lexia Core5 in your classroom instruction and what training you have completed for the software.

You may also be selected to participate in one 30-minute interview about your perceptions of the Lexia software program, how technology influences students learning, and how teachers influence students who struggle to read.

You may complete the survey from your school computer, home computer, or personal device any time before May 1, 2018. Following the survey, if you are selected for the interview portion of the study, I will schedule a time to meet with you for the interview. The total time of your participation will be less than one-hour.

RISKS
While confidential, your survey responses will not be anonymous so that survey responses can be correlated with student growth scores on the Star Reading assessment. However, your individual responses will not be shared with your supervisor and every effort will be made to

protect your confidentiality. However, if you are uncomfortable participating in the survey, you may choose to not participate.

In the unlikely event that some of the survey or interview questions make you uncomfortable or upset, you are always free to decline to answer or to stop your participation at any time. Should you feel discomfort after participating, you may contact either the researcher or Jason Lords, Director of Instruction and Learning for Bonneville School District at lordsj@d93mail.com.

BENEFITS and COMPENSATION
You will not be paid for your participation in this study and there will be no direct benefit to you from participating in this study. However, the information that you provide will help to evaluate the effectiveness of the Lexia Core5 reading program in our district.

EXTENT OF CONFIDENTIALITY
Reasonable efforts will be made to keep the personal information in your research record private and confidential. Any identifiable information obtained in connection with this study will remain confidential and will be disclosed only with your permission or as required by law. The members of the research team, members of the Bonneville School District Leadership Team, and the Boise State University Office of Research Compliance (ORC) may access the data. The ORC monitors research studies to protect the rights and welfare of research participants.

Your name will not be used in any written reports or publications which result from this research, unless you have given explicit permission for us to do this.

Data will be kept for three years (per federal regulations) after the study is complete and then destroyed.

QUESTIONS
If you have any questions or concerns about your participation in this study, you may contact the Principal Investigator, Scott Woolstenhulme: 208-557-6865 or woolstes@d93mail.com or the Co-Investigator, Dr. Ross Perkins: 208-426- 4875 or rossperkins@boisestate.edu.

If you have questions about your rights as a research participant, you may contact the Boise State University Institutional Review Board (IRB), which is concerned with the protection of volunteers in research projects. You may reach the board office between 8:00 AM and 5:00 PM, Monday through Friday, by calling (208) 426-5401 or by writing: Institutional Review Board, Office of Research Compliance, Boise State University, 1910 University Dr., Boise, ID 83725-1138.

PARTICIPATION IS VOLUNTARY
You do not have to be in this study if you do not wish to. You may also refuse to answer any questions you do not want to answer. If you volunteer to be in this study, you may withdraw from it at any time without consequences of any kind or loss of benefits to which you are otherwise entitled.

Do you wish to participate in this study?

○ Yes

○ No

DOCUMENTATION OF CONSENT I have read this form and decided that I will participate in the project described above. Its general purposes, the particulars of involvement and possible risks have been explained to my satisfaction. I understand I can withdraw at any time.

Participant's Name	**Date**
Scott Woolstenhulme, Principal Researcher	Date