2022

STRENGTHENING PHONOLOGICAL PROCESSING AND WORKING MEMORY TO SUPPORT EARLY READING ACQUISITION

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STRENGTHENING PHONOLOGICAL PROCESSING AND WORKING MEMORY TO SUPPORT EARLY READING ACQUISITION

A dissertation submitted in partial fulfillment
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

to the faculty of the

DEPARTMENT OF EDUCATION SPECIALTIES

of

THE SCHOOL OF EDUCATION

at

ST. JOHN'S UNIVERSITY
New York

by

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Date Submitted 11/8/2021 Date Approved 1/30/2022

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ABSTRACT

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The purpose of this research is to investigate the relationship between participating in an online software application focused on phonological processing and working memory and outcomes on foundational reading assessment measures. The online software application utilized was the Sound Reading Program. Students began the intervention working in Sound Reading's Hop, Skip, and Jump program, with a few progressing to the Boost program over the course of the nine-week intervention. A control group at each grade level read or listened to online leveled texts. There were 175 kindergarten and first-grade students included in the study. These students were enrolled in a rural, public elementary school in Central New York State. Student scores on Acadience Reading measures were compared with participation in the intervention. All kindergarten and first grade students at this school with scores available at the beginning of the year and the middle of the year were included in the study. Students were assigned to treatment groups based on the school's predetermined cohort model. This model was utilized at the beginning of the school year to assign students to one of two cohorts or a virtual model in relation to the COVID-19 pandemic. The scores for each cohort were further analyzed to examine the relationship of the number of activities completed in the

intervention and scores on the reading measures. While the data didn't show significant increases in growth based on assignment to the intervention, significant results were documented based on the number of activities completed by students at the kindergarten level and performance on the following measures: Letter Naming Fluency, Nonsense Word Fluency - Correct Letter Sounds, and overall Reading Composite scores. The results indicate promise in the use of online applications to increase phonological processing and working memory skills, as well as the need for further research regarding such approaches.

DEDICATION

I dedicate this dissertation to my daughter and my parents. Your encouragement and support have made this accomplishment possible.

ACKNOWLEDGEMENTS

I made the decision to pursue a doctoral degree after a great deal of deliberation. Ultimately, the desire to engage in intensive study about ways to help my students learn to read surpassed all other obstacles. I would like to acknowledge that this path is not one in which I've traveled alone. The first step was finding an institute of learning that would accommodate my research interests and my obligations as a school administrator. St. John's University has successfully provided this match, and I would like to thank my professors and fellow students for guiding and supporting my journey. I am appreciative of the support of Dr. Cook and my advisor, Dr. Waterman Irwin. The challenges of completing a dissertation, while serving as a school principal during a pandemic, could not have been met without Dr. Waterman Irwin's patience and gentle nudges to keep moving forward.

I would also like to thank the students, teachers, staff members, and administrators at the Sherburne-Earlville Central School District. I am fortunate to be surrounded by individuals who strive to learn and grow every day. I am blessed to have the continued support and guidance of administrators who served before me, and I treasure their wisdom, humor, and friendship. I am also appreciative of the coach who asked me to name one thing I have always wanted to do in my career and wondered aloud about what has kept me from this goal. That single conversation was a turning point for me.

This accomplishment could not have been achieved without the support of my family. My parents continue to model serving others through selfless acts and hard work, and this

has motivated me to be strong whenever I am faced with adversity. My daughter is the epitome of strength and inspires me to be a better person each day. Thank you for your patience during my virtual meetings, supporting me when I needed to bring research and a laptop to your events, sharing the table to do homework during the pandemic, and making me smile on the cloudiest of days.

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CHAPTER 1: INTRODUCTION

Developing reading proficiency to effectively and purposefully facilitate understanding is a significant theme in the Common Core Learning Standards (National Governors Association/Council of Chief State School Officers, 2010). The foundational skills required to reach this level of competency have remained key components of subsequent updates to these standards, including the Next Generation Learning Standards in New York State (New York State Education Department, n.d.). Mastery of these foundational reading skills, then, is essential for students at the primary level as they grow into proficient readers, and it is strongly predictive of further academic achievement and success (Annie E. Casey Foundation, 2010).

Building and strengthening the competencies needed to support sophisticated understanding is a complex undertaking involving many components and, as such, difficulties can arise at any stage that may significantly impact a student's trajectory of progress. Such challenges are widespread in our educational system. According to the National Center for Learning Disabilities (NCLD), an estimated 2.4 million students were identified with specific learning disabilities in the United States in 2014. Of these students, nearly 80 percent had difficulties in the areas of language and reading (Learning Disabilities Association of America, n.d.). While this accounts for the students formally identified for special education support, far more students likely have difficulties without this identification. Code-related skills, including letter name knowledge and phonological awareness, positively correlate with decoding skills at early reading stages (Paratore et al., 2011). Similar to building muscle strength to train for athletic pursuits, the strengthening of phonological processing and memory capacity and efficiency supports further development and can help reduce the need for more intensive services later in a student's education.

Purpose of the Study

This investigation examines the contribution of two foundational skills, phonological processing and working memory, operating together, to build a solid foundation for early reading success. Specifically, the purpose of the quasi-experiment was to determine the association between participating in an online learning intervention and foundational reading skills, including phonemic awareness, working memory, and beginning decoding skills. This intervention was presented to kindergarten and first-grade students within a teacher-directed blended learning environment, as well as in a completely virtual model (dependent on family choice). The intervention provided auditory processing and working memory skills practice through an application delivered on school-provided mobile devices. Fluency in foundational skills at the primary level is a strong predictor of high school outcomes, as well as students' overall interactions with print materials (Cunningham & Stanovich, 1997). Early achievement is especially critical for those students living in poverty, as graduation rates drop significantly for students who live in poverty for a year or more and are not reading proficiently by the end of third grade (Hernandez, 2012).

Background

While literacy is a noun by grammatical standards, the underpinnings supporting literacy are active and complex. Much like a factory, output depends on both input and the strength and efficiency of the systems working within the structure. The role of educators in this process is critical. While they don't monopolize control of the input, they do influence a portion of the supply and can supplement and enhance to meet the needs of our learners. Educators also support the systems within, refining practice to provide the best educational approaches and strategies in efforts to support progress toward rigorous goals.

Language has been part of our composition for tens of thousands of years, but the process of becoming literate, developing fluency in the meaningful application of effective reading and writing skills, requires purposeful study. This dynamic undertaking is central to organized educational systems. Assuming infinite combinations of variables for each individual, outcomes toward this goal fall along a continuum. The challenge for those in pursuit of supporting an upward skew in this spectrum is the development and application of strategies to effectively support the diverse learning needs of all learners. Examining the parts, then, can lead to understandings that will impact the whole. Before students reach a level of synthesis with skills, certain foundational abilities must be acquired. Code-related skills, such as print awareness, phonological awareness, and alphabetic knowledge are predictors of beginning decoding skills (Paratore et al., 2011).

Returning to the analogy of a factory, investigations of internal systems are grounded in information processing theories, and this frame of reference provides an apt basis for the examination of strategies to strengthen such structures. While acknowledging that developing literacy skills involves a multitude of moving components of which research is warranted and advantageous, the exploration at hand narrows the focus to the systems involved when intaking aural stimuli and the immediate response of the brain as areas work to begin to process this information, specifically the phonological and working memory systems. This area of educational focus centers on the ability of the brain to intake and process stimuli to support literacy endeavors, including decoding. Combining phonemic knowledge with adequate memory of associated symbols is essential in successfully decoding print (Wagner & Torgesen, 1987).

Working memory is necessary for many functions that require cognitive attention in our daily lives, including comprehension and planning. As children enter educational settings, a primary focus of the working memory areas of the brain is guiding cognitive literacy processes. Following a multi-component model described by Holmes et al. (2015), the central executive system controls attentional supports to hold information in the working memory area. Specialized areas store verbal and visual-spatial information. This verbal domain is also referred to as the phonological loop, while the visual-spatial domain is known as the visual-spatial sketchpad (Alloway, 2009). The working memory area, then, takes this information either through visual or auditory channels (or both), pulls needed information from long-term memory, and produces a response based on the representation first produced internally (Klingberg et al., 2005). Specifically, working memory supports decoding through the provision of temporary storage for incoming stimuli while sounds are manipulated to produce and combine recognizable phonemes (Knoop-van Campen et al., 2018).

Distinct research in auditory processing and working memory highlights the input and impact of each component. A meta-analysis conducted by the National Early Literacy Panel found that phonological awareness, a skill set requiring students to hear and manipulate the parts, or phonemes, that make up words in one’s language, had a moderate relationship with later reading achievement. Interventions targeted at and/or including phonological awareness training were shown to likely positively impact students' later reading skills. Working memory, including visual and phonological systems, were also cited as predictors for subsequent decoding abilities. The predictive power of phonological short-term memory increases as the reading tasks get more complex and is shown to have a moderate relationship to reading comprehension (National Early Literacy Panel (U.S.) & National Center for Family Literacy (U.S.), 2008). Further, evidence has emerged regarding the symbiotic relationship of these two systems to support overall reading function (Knoop-van Campen et al., 2018).

Significance of the Study

The NCLD (2017) asserts that one in five children present with learning and attention issues, while one in 16 receive support through an Individualized Education Program. These numbers contribute to grim realities for literacy rates in our country. According to the National Assessment of Educational Progress *Reading Report Card*, fourth grade average scale scores have remained within a 10-point range since 1992 and have stabilized within two points since 2007. Unfortunately, these scores fall below the cut-off standard, signifying that many of our students are not meeting grade level expectations in reading (U.S. Department of Education, 2017). Early success in reading is vitally important, as students must develop foundational skills in order to successfully engage with an expanding definition of literacy surfacing in educational, as well as real-world, contexts. Students are now required to apply reading and writing skills in new contexts including digital and disciplinary environments (Gunning, 2020). In order to prepare students to function as literate, contributing citizens, early educators must ensure that they have mastered the necessary prerequisite skills to support continued growth and progress. Reaching proficiency before entering intermediate school is imperative.

Students not developing these skills are four times as likely to drop out of high school when compared to their peers (Annie E. Casey Foundation, 2010).

The timing and type of interventions presented to young children are fundamental considerations in the prevention of reading difficulties. In a meta-analysis of small-group reading interventions, Hall and Burns (2018) found that interventions that were focused on targeted skills were more effective than general interventions. In this study, groups of three or more with similar reading deficits were provided interventions on specific skills, focused on one of the five areas outlined in the National Reading Panel, according to their defined needs. In addition, further support for early intervention was presented, with larger effect sizes for elementary students than at later grade levels.

In relation to working memory, however, studies have predominately focused on older individuals. Significant gains on both trained measures and untrained tasks, including word reading, following a working memory training intervention was described by Loosli et al. (2012). The participants for this study were beyond the kindergarten and first grade age range, with the population drawn from 9 to 11-year-old students. Working memory training programs, such as Cogmed, have increased verbal and visuospatial working memory skills in adults (Dentz et al., 2017). With older populations, working memory training has also positively impacted complex reasoning skills (Klingberg, 2005). Providing this training parallel to emergent reading instruction could positively impact a student's ability to access text fluently.

This study examined the impact of a software application aimed at training phonological processing and verbal working memory skills in an effort to strengthen critical skills related to early reading development. Focusing on working memory interventions earlier in a child's reading development, as well as the connective power of addressing both systems, will add to the existing research of early interventions to prevent later reading difficulties. This investigation will serve to guide primary-level practitioners at the research site and beyond in the application of best practices in early literacy. The study is timely, as the use of online applications will need to be carefully considered in light of the COVID-19 crisis. Information about the efficacy of online learning interventions to support instruction is a critical need in this ever-changing environment.

Research Questions

RQ 1: Is there a difference in the mean growth from the beginning of the year to the middle of year benchmark reading scores between the treatment group receiving an online intervention targeted at phonological processing and working memory and the control group?

RQ 2: Is the level of completion of an online intervention targeted at phonological processing and working memory at the primary level associated with foundational reading achievement scores on middle of year benchmark measures? Is the association the same across both models of instruction (blended and virtual)?

Definition of Terms

Auditory Processing. Auditory processing is a physiological process often defined by deficits in individuals who have difficulty processing auditory information. Subskills of auditory processing include sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal aspects of audition, temporal discrimination, temporal ordering and masking, auditory performance in competing acoustic signals, and auditory performance (American Speech-Language-Hearing Association, 2005).

Blended Learning. Instruction that is provided to students both in-person and through virtual mediums. In this setting, blended learners attended school two days per week and learned from home three days per week.

Virtual Learning. Instruction provided to students through the use of online technologies (Keengwe & Bhargava, 2013).

Working Memory. Prior to storage in long-term memory or removal, our brains hold information within interim storage areas. These areas are immediate memory and working memory. Sousa (2017) described immediate memory using the mental image of a clipboard, a place where we place information until our brain uses it.

CHAPTER 2: REVIEW OF RELATED LITERATURE

Theoretical/Conceptual Framework

Phonological processing and working memory are distinct physiological components of learning. The study of such elements has greatly expanded in the last half-century due to advances in technology. Beginning in the mid-1970s, conceptual models began to shift attention from naturalistic and behavioral perspectives to the study of the physiological workings of the brain. This work grew from Holmes' cognitive processing theory, with the identification of distinct variables supporting reading in the 1950s garnering further interest in the conceptualization and exploration of the specific components, including physical functions, influencing reading efficiency (Unrau & Alvermann, 2013). Gough's information processing model graphically delineated the steps employed during one second of reading (Rumelhart, 2013). While Gough later abandoned specific claims of the lockstep processing of each letter, he did feel that the approach of such examination was valid (Unrau & Alvermann, 2013). This "bottom-up" approach was also presented in Laberge and Samuel's theory of automatic information processing, which described the internal forces supporting automaticity in reading, including internal attention to incoming stimuli (Samuels, 2013). This model included three memory systems, including visual, phonological, and semantic areas (Rumelhart, 2013). The model purported that such functions need to be developed to an automatic level, so that cognitive attention can move to higher order skills, such as comprehension (Rasinski & Mraz, 2008).

Earlier models divided scholars into either top-down or bottom-up processing camps. Top-down proponents focused on what a reader brings to the text, such as context and background knowledge, while bottom-up processing models focused on building meaning synthesizing the print on the page. Rumelhart's interactive model of reading includes components of both perspectives to paint a more complete, and more complex, landscape (Unrau & Alvermann, 2013). Rumelhart expanded on earlier, one-directional information processing models by acknowledging the interconnectedness and simultaneous processing of systems, working together, to enable literacy (Rumelhart, 2013). While this model goes well beyond perceptions that reading occurs letter by letter, it does assume that letter and sound knowledge needs to be developed to automaticity in order for the brain to apply this knowledge when such graphical representations appear in a variety of contexts.

Tightening our lens further, specific models of phonological awareness and working memory have evolved separately; yet, many connections between the two can be articulated, supporting Rumelhart's vision of systems moving separately, and together, to support reading and writing. Katz's Buffalo model for auditory processing emerged in the early 1990s. This multicomponent model included four divisions, all related to auditory processing abilities (decoding, tolerance fading memory, integration, and organization). The decoding portion of this model includes the identification and manipulation of phonemes, hallmarks of the phonological awareness training (Magimairaj & Nagaraj, 2018). The integration category also impacts students learning to read, as this area supports the integration of auditory information with visual information (Jutras et al., 2007). This model forms the basis for the Buffalo Battery, a multi-pronged assessment aimed at diagnosing and remediation of auditory processing disorders (Katz, 2007).

Working memory has also been represented by multicomponent models. In 1968, Atkinson and Shiffrin presented a shifted paradigm, one where short-term memory was not merely an area where information is temporarily stored, but an active center where the brain controls and processes information. They called this area the 'working memory' center (Malmber et al., 2019). In 1974, Baddeley and Hitch further explored working memory through a three-component visualization. This model included the central executive system, viewed as the controller of attention and information flow, sifting through incoming information and directing pertinent data to the appropriate subsystems. Two other components, the visuo-spatial sketchpad and the phonological loop, serve to process specific types of information. The visuospatial sketchpad stores and processes in visual or spatial forms. The phonological loop processes and stores verbal information. The model was intended to provide a basis for further study and research, with the potential for each component to be further articulated and defined (Baddeley, 2017).

As one examines these key models, overlap in skills and functions are apparent. For instance, the short-term auditory memory required for auditory processing is also a critical component of the process utilized in the working memory model to move information through the phonological loop. Attention appears to be involved in both instances. In order to efficiently process information auditorily, one must be able to attend to the incoming sounds. In order for working memory to function successfully, attentional controls must be in place in order to hold information while it is synthesized with plans retrieved from long-term storage areas. While causal relationships have not been established, attentional concerns are noted in individuals with auditory processing and/or working memory difficulties (Gokula et al., 2019). The concurrent presence of difficulties in auditory processing, working memory, and attention further illustrates the intersection of these models.

The relationship between phonological processing and working memory is illustrated by Wagner and Torgesen's phonological processing model (1987), which includes phonological awareness, phonetic recoding in working memory, or the phonological loop, and phonological recoding in lexical access, a skill assessed through rapid automatic naming tasks (Brandenburg et al, 2017). Emergent and early readers must receive letters through visual input, store the sounds of these letters in temporary storage, and then blend the sounds together (Wagner & Torgesen, 1987). The strength of this complex memory process is correlated to later reading success (Nevo & Breznitz, 2011). The current investigation examines key components of Wagner and Torgesen's model, including phonological awareness and the ability to efficiently produce names of given stimuli.

Review of Related Literature

Advances in the Study of Physiological Processes

While interest in brain research as it relates to the acquisition of literacy skills has existed for over a century, advances in technology have increased our understanding of these physiological processes. Cerebral computed tomography (CT) scanning arose in the 1970s, providing a nonsurgical method for researchers to study brain functions. This supported a new horizon in the field of neuropsychology, as researchers sought to better diagnose and treat brain dysfunctions, including those related to literacy skills. Improving on the technological advances provided by CT scanning, magnetic resonance imaging (MRI) appeared in the 1980s, expanding researchers' ability to study brain activity without the need for radioactive substances to highlight the areas being studied (Fletcher et al., 2011). Using these new tools, researchers began to produce visual evidence supporting specific neural processes in the brain and their relationship to certain cognitive skills (Ludvik, 2018). Advances in technology, coupled with the establishment of the International Neuropsychological Society, supported innovative explorations into the neurobiological factors contributing to learning disabilities (Fletcher & Grigorenko, 2017).

In the 1990s, this brain study included functional neuroimaging. Scientists began to study the impact of experimental interventions aimed to improve neural pathways (Ward, 2013). While focus on auditory processing research arose from the study of individuals with diagnosed neurological conditions during the middle of the last century (Magimairaj & Nagaraj, 2018), advances in clinical study has expanded the ability of researchers to conduct intervention investigations with individuals presenting with difficulties in processing stimuli and compare these outcomes with those without known physical abnormalities.

Research in the educational field also began to focus on determining the impact of specific subskills on later reading development. Deficits in phonological processing were found to negatively influence progress in literacy development, specifically the areas of reading and spelling (American Speech-Language-Hearing Association, 2005). This impact is seen early in children’s literacy development, as knowledge of the alphabetic principle and phonological code impact progress in initial reading acquisition (Paratore et al., 2011). Specifically, one’s efficiency in attending to, and manipulating, auditory stimuli at the phoneme level is a strong predictor of reading success (Ehri et al., 2001).

Among the physiological areas activated during reading, the ability of the brain to hold information in working memory is another process correlated with reading achievement (Gathercole et al., 2016). Miller, Galanter, and Pribram introduced the term working memory in 1960, defining it as the brain's ability to quickly retrieve information from storage areas and utilize these plans to perform a function (Magimairaj & Nagaraj, 2018). In 2009, Alloway compared the predictive strength of working memory to intelligence. In this longitudinal study, Alloway found that working memory and domain-specific knowledge were predictors of learning outcomes two years later. In fact, once working memory and prior knowledge were accounted for, traditional intelligence ratings were not a significant predictor of later outcomes. This predictive capability provides great promise, as it refers to a skill that can be improved with training and practice. Gathercole et al. (2016) administered measures of working memory capacity with achievement tests to look for correlations. Associations were noted between verbal and visuo-spatial working memory tasks and reading, with a stronger association established on the verbal working memory tasks (digit span and backward digit span).

Another consideration in the study of working memory is the apparent diminishing working memory capacities of the human population. The ability of adults to effectively chunk pieces of information (such as phone numbers) has decreased over the last fifty years (Sousa, 2017). Although the exact cause of this decline is not fully understood, factors such as trauma (El-Hage et al., 2006) and the use of digital technologies have shown to impact memory capacity (Baumgartner et al., 2014). As this function remains central to learning to read, efforts to mediate weaknesses should be studied to determine best practices for reading instruction. Greater understanding of the physiological functions of the brain in relation to reading will likely be a continued area of significant interest to researchers and practitioners.

Intervening Early

Delivering supplemental, targeted instruction efficiently and effectively is a primary goal of a school's multi-tiered system of support. As skill deficits can be measured at the pre-kindergarten level, these areas can be strengthened by providing intervention at early stages. In a multiyear cluster-randomized controlled trial by Bailet et al. (2011), at-risk preschoolers received 30-minute lessons focusing on pre-reading skills in small groups of four or fewer students. A majority of the students moved from the below average range to the average range on early literacy markers. In addition, the gains persisted for two years post intervention, spanning a critical stage of literacy development. In another study by Goodrich et al. (2017), an early literacy intervention for preschool students focused on phonological awareness training, combined with a professional development program for teachers, significantly improved the phonological awareness skills and print knowledge for English Language Learners, broadening the conviction that educators can respond early to all at-risk learners, including those traditionally underserved.

The time required for these interventions is far less than would be required if gaps persist into later grades. Goldstein et al. (2017) found that just 36 scripted 10-minute lessons in a supplemental intervention produced significant gains on early reading measures. Early interventions are far more efficient than waiting to intervene after students show significant difficulties. Lovett et al. (2017) examined the impact of intervention timing. While a multicomponent intervention yielded positive correlations with reading achievement at the first, second, and third grade levels, students who received the intervention at the first and second grade levels demonstrated significantly greater progress than when the intervention was presented at the third-grade level. In addition, the presentation of the intervention earlier in students' developmental progression had lasting benefits, as the younger students continued to grow at faster rates than their older peers.

In recent years, paradigms shift in how educators approach reading intervention and monitor progress have offered new hope for our struggling students. This transformation was spurred by changes in the identification procedures for students with disabilities. Flexibility to explore alternatives to long-standing identification practices was granted through the reauthorization of the Individuals with Disabilities Act of 2004 (Spear-Swerling, 2004). Schools are no longer required to utilize the IQ-achievement discrepancy model to make such determinations (Council for Exceptional Children, n.d.). This model, often viewed as a "wait to fail" approach, has been supplanted in many states by the adoption of Response to Intervention (RtI) frameworks, especially in regard to primary reading instruction (Slentz, 2013). One of the principal components of an effective RtI approach is intervening before gaps widen to extremes unlikely to be remediated.

Intervening through Technology

Consistency and efficiency are vital factors when choosing interventions for young children. In addition, intervening in reading difficulties through online or blended learning formats is likely to garner greater attention in light of the current crisis prompting school closures in an effort to slow the spread of COVID-19. As this study commenced, other research was being initiated to address concerns of probable deepening gaps due to the closures. The loss of early childcare and education impacted our youngest learners across the globe. While the long-term effects of this disruption remain unknown, a considerable increase of at-risk students was both predicted (McCoy et al., 2021) and being actualized (Engzell et al., 2021). In addition, Engzell et al.'s examination of the learning impact in the Netherlands, a country that experienced relatively shorter school closures and had the advantage of robust internet connectivity, revealed greater loss in students from lower socioeconomic backgrounds (2021). The impact to those with longer disruptions and less internet availability, then, could well surpass this documented loss.

During the school closures, presenting learning opportunities online included the use of educational applications to bolster foundational skills. Studies were initiated to address early concerns of the deepening gaps, such as using gaming formats to support literacy acquisition (Hathaway, 2020). Evidence for the use of such formats has already been established. Applications, such as those developed by the GraphoLearn initiative, have increased the early reading skills of students across the globe (Mehringer et al., 2020; Patel et al., 2018).

Variables within such investigations are important to consider. In 2019, McTigue et al. completed a meta-analysis of 28 studies regarding GraphoGame, a computer-assisted game focused on the acquisition of sound-symbol skills. Their findings suggest that further attention must be given to the relationship between the adult teacher moderator, student, and computer-assisted learning medium. Implementing computer-assisted tools without the influence of a teacher moderator weakened their effects, although teachers still report their value as vehicles to assist in classroom management.

As our current educational landscaping evolves in response to external factors, the potential of mobile learning remediation with teacher oversight for foundational skills should be explored, including phonological processing and working memory. This study explored the effectiveness of an early working memory and phonological processing intervention provided through an online environment. Supported by McTigue et al.'s findings (2019), this environment included an online learning application, as well as teacher interaction to consolidate learning.

CHAPTER 3: METHODS AND PROCEDURES

The purpose of this study is to examine the effectiveness of an online intervention focused on fundamental reading skills (i.e. working memory and phonological processing). This chapter is divided into sections addressing the methods and procedures utilized in this study: research questions, research design, sample, participants, instruments, a description of the treatment, and data analysis. In addition, specific limitations will be addressed.

Research Questions

RQ 1: Is there a difference in the mean growth from the beginning of the year to the middle of year benchmark reading scores between the treatment group receiving an online intervention targeted at phonological processing and working memory and the control group?

RQ 2: Is the level of completion of an online intervention targeted at phonological processing and working memory at the primary level associated with foundational reading achievement scores on middle of year benchmark measures? Is the association the same across both models of instruction (blended and virtual)?

Hypotheses

H1: Students receiving an auditory processing and working memory intervention in kindergarten and first grade will show significantly more growth in foundational reading skills than students who do not receive such intervention. Auditory working memory and phonological awareness skills are associated with efficient reading (Knoop-van Campen et al., 2018), and, hence, remediating these isolated skills will support the acquisition of beginning reading skills.

Null: There will be no significant difference in the achievement growth between students who receive an auditory processing and working memory intervention and those who do not receive such an intervention.

H2a: The level of completion in an online intervention targeted at phonological processing and working memory at the primary level will be associated with foundational reading achievement scores on middle of year benchmark measures

Null: The foundational reading achievement scores at the middle of the year will not be associated with the level of completion in an online intervention focused on phonological awareness and working memory.

H2b: The association between the level of completion in an online intervention targeted at phonological processing and working memory at the primary level will be the same across instructional models (virtual and in-person).

Null: The association between the level of completion in an online intervention targeted at phonological processing and working memory at the primary level will not be the same across instructional models (virtual and in-person).

Research Design

A quasi-experimental design framework was applied in this study. Due to the health and safety requirements imposed during the 2020-2021 school year, the researcher worked with the school to implement the study within the structures established by the district. Students' health and well-being were priorities throughout the study, as well as throughout their entire educational programming. For instance, the district had provided an iPad to each kindergarten and first-grade student for the last two years. While using devices was part of the established program of the school prior to the study, student use and familiarity with the devices grew during the COVID-19 crisis due to the increased reliance on the technology as a medium for teaching and learning. This allowed the intervention to be presented in their classrooms without the need for contact with other outside individuals. It was hoped that the online format would not greatly increase the teachers' workloads, as these professionals were already taxed by the challenges presented by the pandemic.

Information collected during the investigation, including student demographic data and benchmarking scores, was part of established data collection processes at the school. The researcher gained permission from the Superintendent to analyze relevant data in order to gain an understanding of the effectiveness of the intervention. The intervention was part of an ongoing search at the school for software applications to target foundational reading skills at the early primary level. Once the nine-week intervention period concluded, all students at these two grade levels had access to the intervention.

Sample

Kindergarten and first grade students enrolled in an elementary school in one rural, upstate New York school district were included in this study. With an overall district enrollment of approximately 1,300 students, the only elementary school in the district serves approximately 660 of these students. While it was anticipated that approximately 100 kindergarteners and 100 first graders would be enrolled at the time of the study, numbers were slightly lower as several families chose to home school or send their students to private schools during the pandemic. At the onset of the study period, 98 students were enrolled at the kindergarten level, and 85 students were enrolled in the first-grade cohort.

The district includes one elementary school and one combined middle and high school. According to the most recent School Report Card available through the New York State Education Department (2019-2020), 96% of the students were White, 1% were Black or African American, 1% were Hispanic or Latino, 1% were Asian or Native Hawaiian/Other Pacific Islander, and 1% were multiracial. Sixty-one percent of the population was identified as economically disadvantaged, while 22% of the population received special education services under IDEA. It was anticipated that the sample would reflect these statistics.

Parents were able to choose the educational model for their children. Enrolled students could attend school in-person or participate in the school's virtual academy. Of the total cohort of students, 28% of the kindergartners and 21% of the first graders were enrolled in the school's virtual academy during the fall of 2020. These students were taught virtually each day, Monday through Friday, by dedicated virtual instructors. The rest of the students began the school year in the school's blended model. During the summer, school officials assigned students to one of two cohorts. Cohort A attended school in person on Tuesdays and Thursdays and attended virtually on Mondays, Wednesdays, and Fridays. Cohort B attended school in person on Wednesdays and Fridays and attended virtually on Mondays, Tuesdays, and Thursdays.

While this school often considers multiple factors when developing classroom configurations, pandemic protocols required cohorts to be assigned according to transportation needs. The seating chart of each bus run, serving students in preschool through twelfth grade, had to be carefully analyzed to ensure social distancing requirements were met. As a result of this analysis, bus runs were divided into two groups, Cohort A and Cohort B. Individual classes were then created by combining subsets of the A and B Cohorts.

This marked a dramatic change in the process of establishing class lists. At this elementary school in the past, teachers and administrators worked to create balanced classroom environments across grade levels, considering students' academic and social-emotional needs. The pandemic impacting the 2020-2021 school year required focus on distance and space over other considerations. In addition, the school transitioned to more in-person learning mid-fall and prior to the start of this intervention. In this new model, Cohorts A and B attended school in person on Tuesday through Friday. Monday was still a virtual learning day for all students. As the need to return to a blended model was still probable, this researcher decided to continue treatment conditions based on cohort assignments. This model would help to support the teachers in managing the in-person and virtual assignments simultaneously for each group should the need arise.

Participants

Of the 183 students enrolled at the commencement of the intervention, 92 kindergartners and 83 first graders were ultimately included in the study. Students eliminated from the final analysis were those who were missing either beginning or middle benchmark scores. In kindergarten, six enrolled students were not included in the study because of missing scores. Two enrolled first graders were not included under the same circumstance.

Tables 1 and 2 describe the sample in terms of sex, socioeconomic status, IEP status, instructional model and treatment. The socioeconomic status was determined by the number of students who applied and qualified for free or reduced lunch status. As defined by the United States Department of Agriculture, students in families who are between 130 and 185 percent of the Federal poverty line are eligible for reduced-price lunches, while students in families who fall at or below 130 percent of the Federal poverty level are eligible for the free lunch program (United States Department of Agriculture, 2021). While the socioeconomic status reflects numbers reported by the district as those eligible for the free or reduced lunch program, it is important to note that this school offers free meals to all students through the Community Eligibility Provision (CEP). This provision is available to high-poverty schools, defined as those schools in which 40 percent or more of the students receive benefits from the Supplemental Nutrition Assistance Program (Rogus et al, 2018). As all students receive free meals regardless of whether the forms are completed for the free or reduced meal program, the numbers reported may underrepresent this subgroup, especially at the kindergarten level.

Table 1

Kindergarten: Distribution of Sex, Socioeconomic Status, Individual Education Program Status, and Instructional Model (n = 92)

Variables	Frequency	%
Sex		
Female	49	53.3
Male	43	46.7
Socioeconomic Status		
Eligible for free or reduced lunch	30	32.6
Non-eligible for free or reduced lunch	62	67.4
Individual Education Program Status		
Individual Education Program	11	12
No Individual Education Program	81	88
Instructional Model		
In-person	78	84.8
Virtual	14	15.2

Table 2

First Grade: Distribution of Sex, Socioeconomic Status, Individual Education Program Status, and Instructional Model (n = 83)

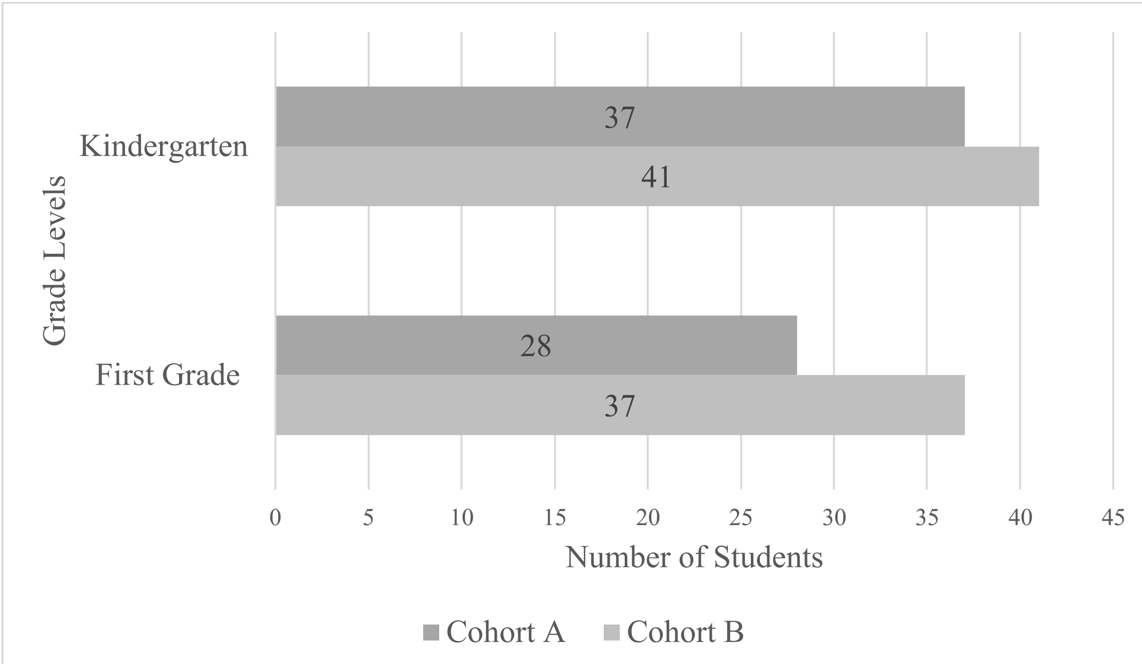
Variables	Frequency	%
Sex		
Female	34	41
Male	49	59
Socioeconomic Status		
Eligible for free or reduced lunch	45	54.2
Non-eligible for free or reduced lunch	38	45.8
Individual Education Program Status		
Individual Education Program	6	7.2
No Individual Education Program	77	92.8
Instructional Model		
In-person	65	78.3
Virtual	18	21.7

Students who were in enrolled in the virtual learning model were extracted from the totals in the analysis related to the first research question. Due to the nature of virtual instruction, it was difficult for teachers to set up A and B cohorts within this model. Students were presented the same curricular activities, including this intervention to complete at home. In addition, the link for the application was pushed out to all the virtual cohorts' iPads making it difficult to maintain a non-treatment group. The virtual students' results were analyzed separately to address Research Question #2, as completion levels were available for all students, both virtual and in-person.

In both grade levels, the treatment was implemented with students in Cohort A. Figure 1 provides a visual display of the distribution of students assigned to each of the in-person cohorts. In kindergarten, a total of 78 students were enrolled in the in-person instructional model. Of those, 37 (47.4%) were identified by the school as Cohort A and 41 (52.6%) were identified by the school as Cohort B. In first grade, 65 students were enrolled in the in-person instructional model. Of those, 28 (43.1%) were identified by the school as Cohort A and 37 (56.9%) were identified by the school as Cohort B.

Figure 1

Distribution Amongst Cohorts for In-Person Learners



Data reflecting the in-person cohort only is further outlined in Tables 3 and 4. In kindergarten, the majority of students in the treatment group were female (62.2%). Twenty-seven percent were eligible for free or reduced lunches, and 8.1% had an Individual Educational Program (IEP). In the control group, the majority of students were male (53.7%). Thirty-four percent were eligible for free or reduced lunches, and 19.5% had an Individual Educational Program (IEP).

Table 3

Kindergarten Students Enrolled in the In-Person Model - Distribution of Sex, Socioeconomic Status, and Individual Education Plan Status Within Conditions (n=78)

	Cohort A Treatment (*n* = 37)		Cohort B Control (*n* = 41)	
Variable	Frequency	%	Frequency	%
Sex				
Female	23	62.2	19	46.3
Male	14	37.8	22	53.7
Socioeconomic Status				
Eligible for free or reduced lunch	10	27.0	14	34.1
Non-eligible for free or reduced lunch	27	73.0	27	65.9
Individual Education Program Status				
Individual Education Program	3	8.1	8	19.5
No Individual Education Program	34	91.9	33	80.5

In first grade, the majority of students in the treatment group were male (60.7%). Approximately 61% were eligible for free or reduced lunches and 7.1% had an Individual Educational Program (IEP). In the control group, the majority of students were also male (59.5%). Of those, 40.5% were eligible for free or reduced lunches, and 10.8% had an Individual Educational Program (IEP). This information is presented in Table 4.

Table 4

First Grade Students Enrolled in the In-Person Model - Distribution of Sex, Socioeconomic Status, and Individual Education Program Status Within Conditions (n=65)

	Cohort A Treatment (n = 28)		Cohort B Control (n = 37)	
Variable	Frequency	%	Frequency	%
Sex				
Female	11	39.3	15	40.5
Male	17	60.7	22	59.5
Socioeconomic Status				
Eligible for free or reduced lunch	17	60.7	15	40.5
Non-eligible for free or reduced lunch	11	39.3	22	59.5
Individual Education Program Status				
Individual Education Program	2	7.1	4	10.8
No Individual Education Program	26	92.9	33	89.2

Groups, then, were not perfectly balanced, exposing a limitation of the quasi-experimental design. Multiple regression was applied in the data analysis for Research Question #2 to account for these differences. Distributions of variables for each cohort is presented in Figure 2 through Figure 7.

Figure 2

Kindergarten: Frequency of Sex Variable Across Treatments

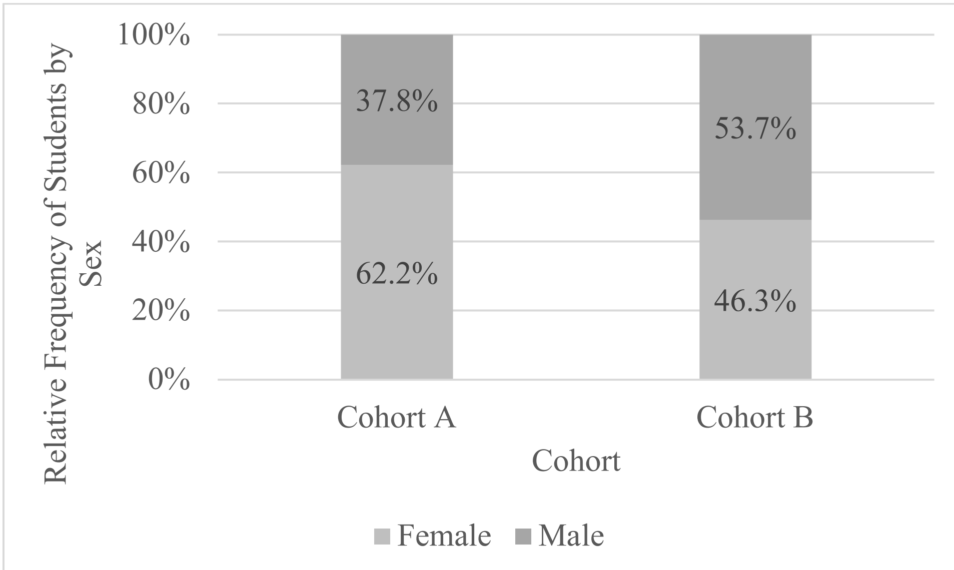


Figure 3

First Grade: Frequency of Sex Variable Across Treatments

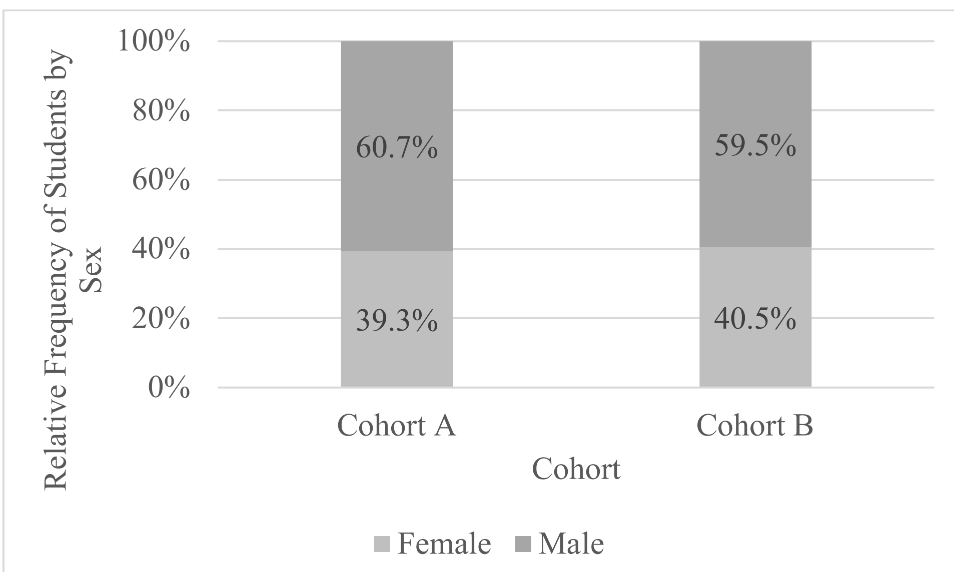


Figure 4

Kindergarten: Frequency of Students with Individual Educational Programs (IEPs) Across Treatments

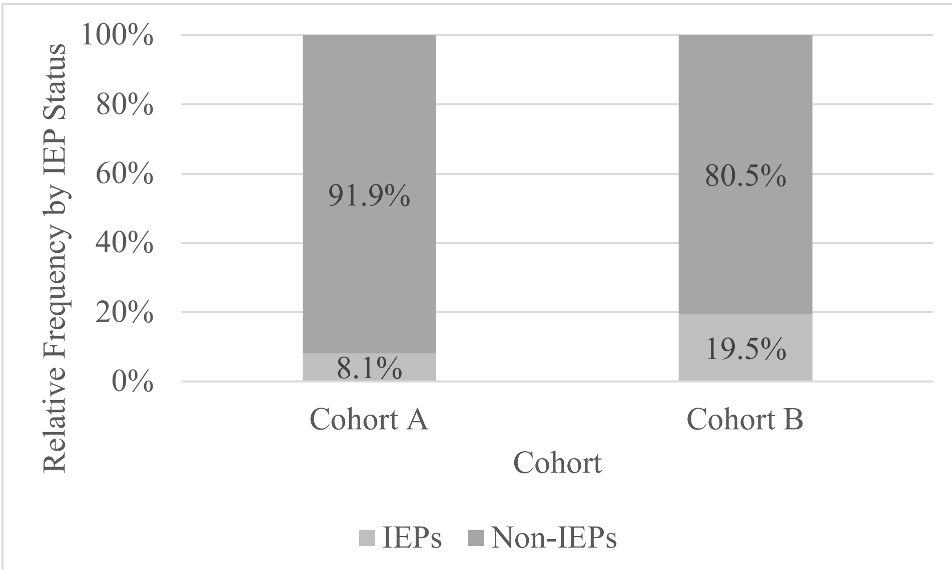


Figure 5

First Grade: Frequency of Students with Individual Education Programs (IEPs) Across Treatments

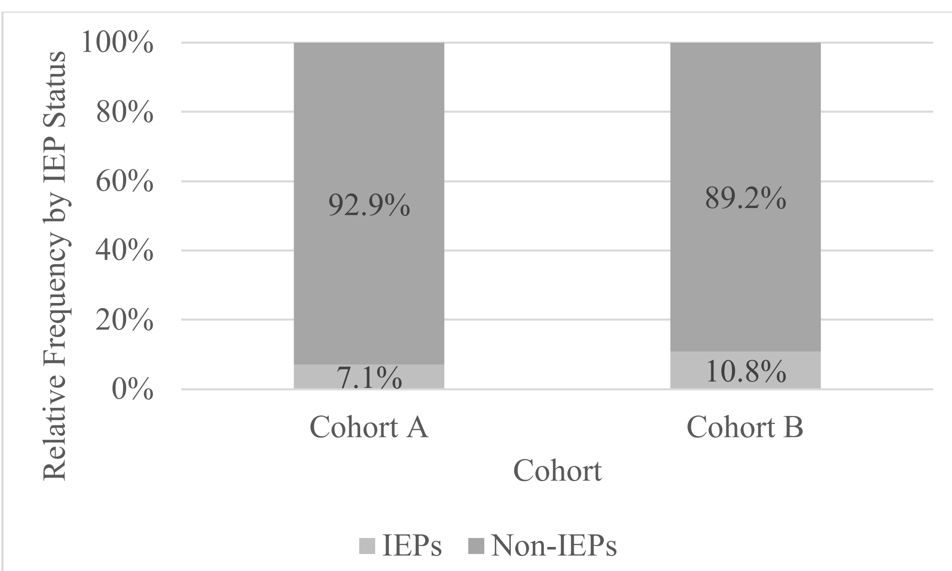
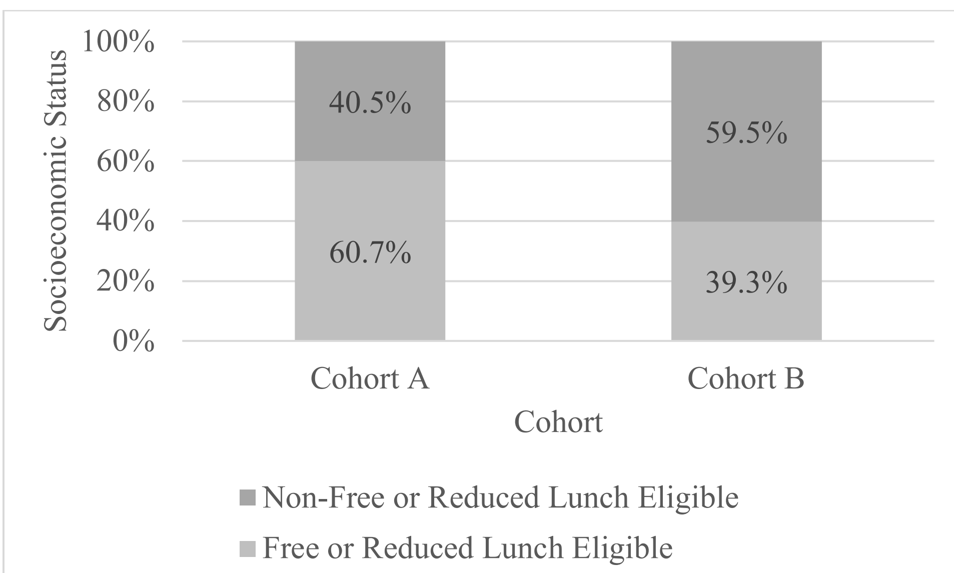


Figure 6

Kindergarten: Frequency of Socioeconomic Status Across Treatments

Figure 7

First Grade: Frequency of Socioeconomical Status



Instruments

This school has used the DIBELS Next Benchmarking Measures since 2011 to assess the growth of all students three times per year, as well as to progress monitor students who are at risk of not reaching standards. The DIBELS Next measures have recently been renamed to Acadience Reading (University of Oregon Center on Teaching and Learning, n.d.). The school is using these measures, as well as entering and analyzing data through the Acadience Data Management platform. These short fluency measures are used for universal screening, benchmarking and progress monitoring in kindergarten through fifth grade at this school and provide relevant data to help support the school's Multi-Tiered Systems of Support initiatives.

At the kindergarten level, students were administered two Acadience Reading measures at the beginning of the school year: First Sound Fluency and Letter Naming Fluency. Both measures were administered individually. First Sound Fluency assesses a student's ability to produce the initial sounds in words. Students receive full credit for producing an isolated sound and partial credit for producing a correct initial blend. This measure addresses phonological awareness. Letter Naming Fluency requires students to produce the name of a letter presented in a random order. While this measure does not address one of the five core components identified by the report from the National Reading Panel (National Reading Panel (U.S.) & National Institute of Child Health and Human Development (U.S.), 2000), it serves as an unique supporter of growth in other areas of reading, such as letter sound fluency, and is predictive of later reading success (Clemens, 2017). As a measure of rapid automatic naming, deficits in this area can indicate further difficulties in word reading, both as an independent factor, as well as serving as part of a double deficit for those with difficulties in rapid naming and phonological awareness (Vander Stappen, C. & Van Reybroeck, M., 2018).

At mid-year, kindergarten students were assessed with the First Sound Fluency and Letter Naming Fluency measures, as well as two additional measures. While Phoneme Segmentation Fluency is added to the composite battery at this point, it was not utilized in this study due to concerns with its reliability coefficients. The areas of alphabetic principles and phonics are also assessed through the Nonsense Word Fluency measure, and this measure was analyzed. This measure requires the students to apply skills to produce and blend sounds to decode unfamiliar words.

First graders were assessed in the beginning of the year with the Nonsense Word Fluency measure. These students are expected to more efficiently produce a whole word, rather than the production of sound by sound. At the mid-year point, this measure was repeated and Oral Reading Fluency, a measure of decoding, was added. In this measure, real words are given in the context of a short reading passage. Students apply skills to read the passage (University of Oregon Center on Teaching & Learning, n.d.).

Reliability

The DIBELS Next measures, written by Dr. Roland Good and Dr. Ruth Kaminski, are now being offered through Acadience Reading. Acadience Reading has presented the reliability of its measures in the Acadience Reading K-6 Technical Manual (Good et al., 2019). At the kindergarten level, measures were analyzed for alternate form and inter-rater reliability. Based on their studies, the First Sound Fluency reliability estimate for a single form was .82, Letter Naming Fluency was .86. Nonsense Word Fluency – Correct Letter Sounds was .71, and Nonsense Word Fluency was .92. All inter-rater reliability estimates were greater than .90. At the first-grade level, Nonsense Word Fluency (both Correct Letter Sounds and Whole Words Read) coefficients were above .84. Oral Reading Fluency was .95. Inter-rater reliability estimates for first grade were also greater than .90. In addition, the authors reported that test-retest reliability for Nonsense Word Fluency – Correct Letter Sounds was .76 and Nonsense Word Fluency – Whole Words Read was .70. Overall, coefficients are high across these reliability measures.

Validity

As reported in the Acadience Reading K-6 Technical Manual (Good et al., 2019), validity was analyzed with data from four separate studies examining content validity, criterion-related validity, and discriminant validity. Content validity is the assurance that the assessment tasks are representative of the skills developers purport the assessments to measure. The Acadience Reading measures were designed to test foundational reading skills outlined by the National Reading Panel (National Reading Panel (U.S.) & National Institute of Child Health and Human Development (U.S.), 2000). Specifically, kindergarten and beginning first grade measures focus on Phonemic Awareness (First Sound Fluency and Phoneme Segmentation Fluency), the Alphabetic Principle, and Basic Phonics (Nonsense Word Fluency, Correct Letter Sounds and Whole Words Read). At the mid-year point in first grade, oral reading fluency is added, expanding the skills assessed to Basic Phonics and Word Attack Skills, Accurate and Fluent Reading of Connected Text, and Reading Comprehension.

Criterion-related validity, the ability of a measure to be significantly correlated to another measure, was examined utilizing comparisons with the Group Reading

Assessment and Diagnostic Evaluation (GRADE) and the Comprehensive Test of Phonological Processing (CTOPP) at the early levels. Validity was also examined in comparison to other Acadience Reading measures. When compared to the GRADE, the beginning of the year and middle of the year measures at kindergarten and first grade were positively correlated to Spring GRADE measures at the moderate to moderate-strong range, except for Nonsense Word Fluency, Whole Words Read at the mid-year point in kindergarten (see Table 5).

Table 5

Criterion-Related Validity for Acadience Reading Measures With Group Reading Assessment & Diagnostic Evaluation - Total Test

	Grade Level	
Beginning of Year Measure	Kindergarten	1st Grade
First Sound Fluency	.52	
Letter Naming Fluency	.39	.54
Nonsense Word Fluency - Correct Letter Sounds		.43
Nonsense Word Fluency - Correct Letter Sounds		.39
Middle of Year Measure	Kindergarten	1st Grade
First Sound Fluency	.40	
Letter Naming Fluency	.35	
Nonsense Word Fluency - Correct Letter Sounds	.47	.51
Nonsense Word Fluency - Correct Letter Sounds	.19*	.52

$p < .001$; * $p < .05$.

(Good et al., 2019)

Moderate to strong concurrent validity was also established when comparing Acadience and GRADE measures administered at the end of the school year. Concurrent validity was moderate when comparing First Sound Fluency to selected subtests of the CTOPP (.45 for the Phonemic Awareness Composite and .49 for the Elision Subtest). As displayed in Table 6, all the measures were also positively correlated to later scores of Acadience Reading Measures at the moderate to strong range, with the highest predictability being Nonsense Word Fluency - Correct Letter Sounds and Nonsense Word Fluency - Whole Words Read at mid-year first grade (.82 and .79).

Table 6

Predictive Criterion-Related Validity for all Acadience Reading Measures With the Reading Composite Score

	Grade Level	
Middle of Year	Kindergarten	1st Grade
First Sound Fluency	.57	
Letter Naming Fluency	.60	.65
Nonsense Word Fluency - Correct Letter Sounds		.82
Nonsense Word Fluency - Correct Letter Sounds		.79

All correlations significant, $p < .001$.

(Good et al., 2019)

To examine discriminant validity, researchers analyzed Acadience Reading Composite scores when divided into two groups by their scores on the GRADE assessments, those who fell below the 40th percentile and those who scored at or above the 40th percentile. Cohen's *d* effect sizes were large at the kindergarten level (1.03 at the beginning of the year, 0.94 at the middle of the year, and 0.62 at the end of the year) and first grade (1.11 at the beginning of the year, 1.58 at the middle of the year, and 1.85 at the end of the year). The large effect size indicated that the Acadience Reading scores significantly distinguished students who scored below the 40th percentile on the GRADE to those who scored at or above the 40th percentile on the Acadience Reading measures (Good et al., 2019).

Treatment/Intervention

The intervention provided to students served as the treatment variable. Other variables analyzed for Research Question 2 included student characteristic variables, including sex, socioeconomic status, and Individual Education Program status. Students in the treatment group utilized software focused on auditory processing and working memory. The software is produced by Sound Reading Solutions, Inc. Specifically, the Hop, Skip & Jump and Boost applications were utilized. While the Hop, Skip, & Jump application is targeted to Pre-K and K students, it was also utilized with 1st grade students. The rationale behind this decision was constructed through dialogue with the teachers, who described how kindergartners were greatly impacted by the school closure the previous semester. These teachers voiced strong concerns about gaps in critical foundational knowledge. The pre-test data substantiated this concern.

Table 7 presents the beginning of the year historical scores for First Sound Fluency and Nonsense Word Fluency - Correct Letter Sounds at this particular school. The numbers reflect the percentage of students identified as meeting the benchmark goal for each measure. During the 2019-2020 school year, the District switched to another platform for benchmarking, and there was no evidence of concurrent predictability with the DIBELS Next measures. Therefore, this year was omitted from the table. The District made the decision to switch back to the Acadience Data Management system in 2020-2021, returning to the measures formally known as DIBELS Next.

Table 7

Comparison of Percentage of Students Scoring at or Above the Benchmark Goal – Beginning of First Grade

Year	Phoneme Segmentation Fluency	Nonsense Word Fluency – Correct Letter Sounds
2015	73%	41%
2016	68%	45%
2017	74%	41%
2018	69%	36%
2020	39%	30%

The Hop, Skip, & Jump and Boost interventions are interactive, online platforms focused on the development of auditory processing skills. In this game-like environment, students are asked to discriminate phonemes, identify rhyming words, and count the sounds in words. Working memory tasks are also featured, including automatic naming exercises (Sound Reading, n.d.). The activities for each application are outlined in Tables 8 and 9.

Table 8

Number of Sound Reading Activities by Level – Hop, Skip, & Jump

Number of Activities for Each Skill Addressed					
Level	Comprehen-sion	Phonemic Awareness	Word Reading Accuracy	Auditory Discrimina-tion	Automaticity/ Fluency
1	1	13	2	1	3
2	0	11	3	1	5
3	0	13	2	1	4
4	0	10	0	2	8
5	0	11	2	3	4
6	0	15	1	1	3
7	0	10	1	6	3
8	0	10	2	4	4
9	0	11	1	5	3
10	0	8	2	7	3
11	0	8	6	5	1
12	0	11	2	6	1
13	0	9	2	7	2
14	0	11	1	5	3
15	0	10	1	3	6

Table 9

Number of Sound Reading Activities by Level – Boost

	Number of Activities for Each Skill Addressed				
Level	Comprehen-sion	Phonemic Awareness	Word Reading Accuracy	Auditory Discrimina-tion	Automaticity/ Fluency
1	1	6	6	2	5
2	2	7	6	2	3
3	3	7	4	3	3
4	5	7	0	2	6
5	1	9	1	4	5
6	3	7	4	3	3
7	1	5	2	9	3
8	3	7	2	4	4
9	1	12	2	2	3
10	1	9	7	0	3
11	2	5	7	2	4
12	2	7	5	2	4
13	1	8	5	2	4
14	5	6	3	2	4
15	5	7	3	1	4
16	4	7	4	0	5

While the Sound Reading program has a placement assessment, it was determined that all kindergarten and first-grade students would begin with Hop, Skip, & Jump to address the deficits previously reported. Once students had completed Hop, Skip, & Jump, they were moved to the Boost application. Students are assigned school-issued iPads to use throughout the school year and used these devices to access the program. A kindergarten interventionist and a first-grade interventionist participated in training with an educational consultant from the company. In addition, a follow-up training was held for all teachers implementing the intervention. The interventionists, teachers, and support staff managed the rollout of the program, including supporting students in bookmarking the webpage on the internet browser on their iPad and guiding them in the login process.

The intervention occurred over a nine-week period between the fall and the winter benchmarks (September and January). One week encompassed the winter break, and no expectation for participation was communicated for this week. Each student in the treatment group had time in their schedule to access the applications in their classroom. Initially, the intervention was planned to be delivered in a blended learning model, where this intervention would be accessed from home two times per week. Students, then, would complete four sessions of 15 minutes, two at home and two at school. Health data was favorable to bring students back together four days per week prior to the beginning of the intervention. Cohorts A and B were combined in this in-person model. While many factors, including health and safety protocols, weighed heavily on teachers' minds, the original goal of Cohort A engaging in the intervention four days per week, for at least fifteen minutes per session, remained. The time allocated to this activity in many classrooms occurred as a rotation during small group reading time. Teacher aides were available to support students with technical issues. For students enrolled in the virtual academy, teachers described and supported the implementation of the program remotely.

Students in the control group utilized other software already available to students at this school. This software, Raz-Kids, has been used at the primary level for the last three years to support its reading program. Students were given an equivalent amount of time to listen and/or read e-books and answer comprehension questions presented by this software. All students have access to this software on their iPads. As with the treatment group, time was allocated as a rotation during small group reading time for many students, with the support of teacher aides for technological and task-related concerns. Following the intervention period, the Sound Reading application was made available to students in both conditions.

Data Analysis

Student progress was measured with specific assessments of the Acadience Reading measures. Resulting data was analyzed with IBM Statistical Package for the Social Sciences (Version 27) software. To address Research Question #1, mean growth was calculated for each group (treatment and control) for measures with two data points. For measures only presented at the middle of the year, means were compared. Independent t-tests were applied to determine if the differences between the means, or change in means, were statistically significant. As there are multiple independent variables (treatment/level of exposure, sex, socioeconomic status, and Individual Education Program status) and one dependent variable (outcomes on mid-year assessments), multiple regression analysis was applied to determine the impact of the intervention across variables for Research Question #2.

Limitations

As this study was planned to occur during a partial school closure, efforts were made to ensure that students were utilizing the software on a consistent basis. However, the unique challenges of the pandemic did tax the consistency of the intervention. For instance, as need arose, students were placed in quarantine with differing levels of home support to maintain classwork. Time and activity logs were accessed from the application, however, so that results could be reviewed relative to the levels completed for each student in the treatment group.

The results of this study should be considered through a correlational lens, not causal, as participants were not randomly assigned to groups. Overall instructional models were determined through family decisions (virtual vs. blended). Students in the virtual model were assigned to virtual class and instructor. Blended, in-person classes were developed by combining A and B cohorts to form balanced class lists. Cohort A was assigned to the treatment group, and Cohort B was assigned to the control group. The decision to assign a cohort to the intervention, as opposed to random selection, was made in order to support the teachers in the event that the school returned to an instructional model that included only one cohort present at school at a time. For this quasi-experiment, all virtual students were removed from the data analysis for Research Question #1 and assigned as a separate treatment group for Research Question #2, as all virtual students had access to the intervention and activity completion logs were available for each of these students.

Delimitations

This study confined itself to kindergarten and first grade students and teachers during a small portion of their school day or work-at-home time. For both scenarios, the intervention was part of the students' independent practice time.

CHAPTER 4: RESULTS

The results of the research questions are presented in this chapter. This quasi-experimental study focused on the beginning of the year and middle of the year benchmark reading scores of kindergarteners and first graders. While the study included 175 students, Research Question 1 focused on students learning in-person. The total for this cohort of students was 143. Research Question 2 also includes students enrolled in the school's virtual academy. This additional group of 32 students will be presented separately, as instruction outside of the intervention differed for in-person and virtual learners.

This study was conducted to determine if an online application supporting phonological processing and working memory would have an effect on the mid-year reading scores of kindergartners and first graders. The independent variable was the treatment condition, while dependent variables included changes in scores for measures that were presented at the beginning and middle of the year or middle of the year scores for those measures only presented at this time. The chapter presents the group and statistical test analyses for each research question. Group mean differences and statistical test analyses were computed using SPSS (Version 27).

Research Question #1 – Group Statistics

Is there a difference in the mean growth from the beginning of the year to the middle of year benchmark reading scores between the treatment group receiving an online intervention targeted at phonological processing and working memory and the control group?

The mean growth from the beginning of the year to the middle of year benchmark reading scores for each treatment was determined by comparing the means of each group for each subtest included in the study. For kindergarten, beginning of the year and middle of the year scores were available for First Sound Fluency, Letter Naming Fluency, Nonsense Word Fluency, and the overall Reading Composite Score. While Phoneme Segmentation Fluency is included in the Reading Composite Score at the mid-year point, it was not analyzed individually due to its decreased reliability coefficients. Focus on the individual areas of First Sound Fluency, Letter Naming Fluency, and Nonsense Word Fluency is reviewed.

Of the 78 in-person kindergarten students included in the study, 37 were part of the treatment group and 41 were part of the control group. Little difference between group means was evidenced in First Sound Fluency from the beginning of the year to the middle of the year (Table 10). The mean difference of the treatment group was higher for the control group in Letter Naming Fluency (Table 11). Nonsense Word Fluency - Correct Letter Sounds and Nonsense Word Fluency - Whole Words Read are first presented at the mid-year assessment in kindergarten. In this area, the control group had a higher mean difference than the treatment group (Table 12) in Correct Letter Sounds, while the treatment group had a slighter higher mean in Whole Words Read (Table 13).

Table 10

Kindergarten First Sound Fluency (Group Statistics, n = 78)

	Beginning		Middle		Gain
Cohort	Mean	SD	Mean	SD	
Treatment (*n* = 37)	12.22	15.55	40.57	11.64	28.35
Control (*n* = 41)	8.85	10.65	37.54	14.74	28.69

Table 11

Kindergarten Letter Naming Fluency (Group Statistics, n = 78)

	Beginning		Middle		Gain
Cohort	Mean	SD	Mean	SD	
Treatment (*n* = 37)	13.41	11.89	32.41	14.25	19.00
Control (*n* = 41)	11.59	8.80	27.59	14.93	16.00

Table 12

Kindergarten Nonsense Word Fluency - Correct Letter Sounds (Group Statistics, n = 78)

	Beginning		Middle		Gain
Cohort	Mean	SD	Mean	SD	
Treatment (*n* = 37)			20.92	11.94	
Control (*n* = 41)			20.66	13.77	

Note: Nonsense Word Fluency - Correct Letter Sounds is not part of the assessment battery at the beginning of the year.

Table 13

Kindergarten Nonsense Word Fluency - Whole Words Read (Group Statistics, n = 78)

	Beginning		Middle		Gain
Cohort	Mean	SD	Mean	SD	
Treatment (*n* = 37)			1.00	3.24	
Control (*n* = 41)			41.00	2.87	

Note: Nonsense Word Fluency, Whole Words Read is not part of the assessment battery at the beginning of the year.

In first grade, 65 in-person students were included in the analysis for Research Question #1. Of these students, 28 were part of the treatment group and 37 were part of the control group. At the first-grade level, mean differences were calculated for Nonsense Word Fluency - Correct Letter Sounds and Nonsense Word Fluency - Whole Words Read. The Acadience Reading Assessment Battery also introduces Oral Reading Fluency - Words Correct at the mid-year point, and the mean differences for each group are also presented for this measure. The treatment group had a higher mean gain for Nonsense Word Fluency - Correct Letter Sounds (Table 14), but a decreased gain in comparison with the control group for Nonsense Word Fluency, Whole Words Read (Table 15). The mean score at the mid-year assessment for Oral Reading Fluency - Words Correct was slightly higher for the treatment group (Table 16).

Table 14

First Grade Nonsense Word Fluency - Correct Letter Sounds (Group Statistics, n = 65)

	Beginning		Middle		Gain
Cohort	Mean	SD	Mean	SD	
Treatment (*n* = 28)	18.96	13.45	45.25	20.79	26.29
Control (*n* = 37)	23.49	18.06	44.68	25.66	21.19

Table 15

First Grade Nonsense *Word Fluency - Whole Words Read (Group Statistics, n = 65)*

	Beginning		Middle		Gain
Cohort	Mean	SD	Mean	SD	
Treatment (*n* = 28)	1.36	3.77	8.82	9.36	7.46
Control (*n* = 37)	1.24	5.30	10.05	9.82	8.81

Table 16

First Grade Oral Reading Fluency - Words Correct (Group Statistics, n = 65)

	Beginning		Middle		Gain
Cohort	Mean	SD	Mean	SD	
Treatment (*n* = 28)			19.43	21.01	
Control (*n* = 37)			20.22	20.30	

Note: Oral Reading Fluency - Words Correct is not part of the assessment battery at the beginning of the year.

Research Question #1 – Statistical Analyses

Independent t-tests were utilized to analyze the means of the separate groups (treatment and control) to determine significance. At the kindergarten level, this process was applied using the mean differences of the control and treatment groups measures with two data points: First Sound Fluency and Letter Naming Fluency, as displayed in Table 17. As the significance for both of these measures is greater than .05, the null hypothesis is accepted. There was no significant difference between the mean change scores for the treatment and control groups for First Sound Fluency and Letter Naming Fluency at the kindergarten level.

Table 17

Kindergarten First Sound Fluency and Letter Naming Fluency Mean Change (Independent Samples t-test, n = 78)

Measure	F	Sig.	T	df	Sig. (2-tailed)	MD	SED
First Sound Fluency	1.65	.203	-.111	76	.912	-.33	3.00
Letter Naming Fluency	0.06	.810	1.25	76	.215	3.00	2.40

The mean differences between the control and treatment groups for Nonsense Word Fluency - Correct Letter Sounds and Nonsense Word Fluency, Whole Words Read was also analyzed utilizing mid-year scores. As these scores were only collected once, the means were analyzed between the two groups utilizing the mid-year scores (Table 18).

Table 18

Kindergarten Nonsense Word Fluency - Correct Letter Sounds and Whole Words Read (Independent Samples t-test, n = 78)

Measure	F	Sig.	T	df	Sig. (2-tailed)	MD	SED
Nonsense Word Fluency – Correct Letter Sounds	.53	.471	.089	76	.930	.26	2.93
Nonsense Word Fluency – Whole Words Read	.55	.460	.385	76	.699	.27	0.70

Analyses of both Nonsense Word Fluency measures at the mid-year point for kindergarten also support the null hypothesis, as there is no significant difference between the control and treatments groups. While the other scores were far from reaching significance, the change in Letter Naming Fluency was the closest to reaching a significant level, with a p value of .215.

First grade measures include: Nonsense Word Fluency - Correct Letter Sounds and Whole Words Read and Oral Reading Fluency - Total Words. The significance of the change from beginning to middle of the year for Nonsense Word Fluency for both the treatment and control group are presented in Table 19. As presented, both measures did not reach a level of significance between the control and treatment groups.

Table 19

First Grade Nonsense Word Fluency - Correct Letter Sounds and Whole Words Read (Independent Samples t-test, n = 65)

Measure	F	Sig.	T	df	Sig. (2-tailed)	MD	SED
Nonsense Word Fluency – Correct Letter Sounds	0.76	.386	1.291	63	.201	5.10	3.95
Nonsense Word Fluency – Whole Words Read	.008	.929	-.695	63	.490	-1.35	1.94

Oral Reading Fluency, Total Words is presented for the first time at the mid-year point as part of Acadience Reading. The significance in the difference in means between these two scores is presented in Table 20.

Table 20

First Grade Oral Reading Fluency - Total Words (Independent Samples t-test, n = 65)

Measure	F	Sig.	T	df	Sig. (2-tailed)	MD	SED
Oral Reading Fluency - Total Words	.172	.680	-.153	63	.879	-.788	5.162

As presented, the null hypothesis was accepted for all the measures across both kindergarten and first grade. There was no significant difference between the outcomes for the control and the treatment group. As described in the limitations section, however, the nature of the school year and challenges with the pandemic resulted in consistency issues with time spent on the application for the treatment group. In Research Question #2, more attention to results in relation to levels of interaction with the application are explored.

Research Question #2 – Group Statistics

Is the level of completion of an online intervention targeted at phonological processing and working memory at the primary level associated with foundational reading achievement scores on middle of year benchmark measures?

The treatment intervention, Sound Reading, offers data regarding the amount of time, as well as the activities completed, for each student that accesses the program. After a review of this data with the teachers, it was determined that the activities completed more closely reflected the level of interaction with the program. The Hop, Skip, and Jump and Boost programs from Sound Reading Solutions presents 20 activities at each level. Hop, Skip, and Jump includes 15 levels, while 16 levels are presented in Boost. Activities get progressively harder as students move up levels. The amount of activities completed was added as an independent variable. Sex, socioeconomic status, and IEP status were also analyzed as independent variables.

Students in the intervention group completed a range of activities. While the expectation was communicated that students were to engage in the Sound Reading application for 15 minutes per day for at least four days per week, teachers reported a number of obstacles for this assumption. Namely, the impact of the pandemic was a primary factor. Quarantines and altered schedules due to staffing shortages were reported. Sound Reading could be assigned to be completed at home during an absence or quarantine, but making up missed sessions was difficult, as teachers used available time to provide direct teaching when students returned. Table 21 and Table 22 present the mean and range of activities completed by the intervention group.

Table 21

Activities Completed by Intervention Groups Over Nine Weeks (In-Person Model)

Grade Level	Minimum	Maximum	Mean	SD
Kindergarten (*n* = 37)	40.00	280.00	157.30	60.95
First Grade (*n* = 28)	40.00	300.00	177.86	71.25

Table 22

Activities Completed by Intervention Groups Over Nine Weeks (Virtual Model)

Grade Level	Minimum	Maximum	Mean	SD
Kindergarten (*n* = 14)	40.00	280.00	157.30	60.95
First Grade (*n* = 18)	20.00	560.00	207.14	153.64

Research Question #2 – Statistical Analyses

Multiple regressions were run to predict mid-year reading scores from the following independent variables: sex, IEP status, SES status, total activities completed, and beginning of the year scores related to each specific measure. An analysis was applied to each measure administered and included in the study. In addition, this question addressed the virtual learners. This group of participants were omitted from Research Question #1, as there wasn't a control group for comparison in this instructional approach. The multiple regression model statistically significantly predicted mid-year benchmark scores across grades and measures, as displayed in Table 23.

Table 23

Multiple Regression Model Summaries Across Grades and Measures

Grade	Model		*n*	F	Sig.	ΔR^2
K	IP	First Sound Fluency	37	5.96	.001	.41
K	V	First Sound Fluency	14	4.56	.027	.52
K	IP	Letter Naming Fluency	37	6.63	.001	.44
K	V	Letter Naming Fluency	14	4.52	.028	.52
K	IP	Reading Composite Score	37	13.16	<.001	.63
K	V	Reading Composite Score	14	5.08	.020	.56
1	IP	Nonsense Word Fluency - Correct Letter Sounds	28	6.08	.001	.49
1	V	Nonsense Word Fluency - Correct Letter Sounds	18	15.76	<.001	.78
1	IP	Nonsense Word Fluency - Whole Words Read	28	4.28	.007	.38
1	V	Nonsense Word Fluency - Whole Words Read	18	6.55	.004	.57
1	IP	Reading Composite Score	28	5.97	.001	.48
1	V	Reading Composite Score	18	13.00	<.001	.78

Note. IP = in-person model; V = virtual model; ΔR^2 = adjusted R^2.

Regression coefficients and standard errors can be found for each measure, grade level, and instructional model, beginning with Table 24. In kindergarten, no single factor was statistically significant for the First Sound Fluency measure (see Table 24). The Letter Naming Fluency score at the beginning of the year did show statistical significance, however, across both the in-person and virtual models, as displayed in Table 25. For in-person learners, the number of activities completed in Sound Reading was also a significant predictor variable for mid-year scores on Letter Naming Fluency. Analysis of Reading Composite (overall battery) scores at the kindergarten level show that beginning scores in this area were significant for both in-person and virtual learners, as presented in Table 26. The number of activities completed in the Sound Reading Program was also a significant predictor of mid-year Reading Composite scores for in-person kindergarten students.

Table 24

Multiple Regression Results for Mid-Year First Sound Fluency (Kindergarten)

Variable	*B*	*SE*	*t*	*p*	95% CI
	Mid-Year Achievement on First Sound Fluency (In-Person Model)				
Constant	32.27	5.52	5.84	.001	[21.01, 43.53]
Sex	5.21	3.47	1.50	.143	[-1.86, 12.27]
Individual Educational Program Status	-5.23	6.07	-.86	.396	[-17.60, 7.15]
Socioeconomic Status	.83	3.49	.24	.814	[-6.29, 7.94]
Beginning First Sound Fluency Score	.43	.11	4.10	.216	[.22, .64]
Activities Completed	.00	.03	.004	.997	[-.05, .05]
	Mid-Year Achievement on First Sound Fluency (Virtual Model)				
Constant	17.38	5.38	3.23	.010	[5.22, 29.54]
Sex	-4.3	5.64	-.761	.47	[-17.05, 8.46]
Socioeconomic Status	-7.51	6.29	-1.20	.263	[-21.73, 6.71]
Beginning First Sound Fluency Score	.39	.26	1.48	.174	[.208, .988]
Activities Completed	.04	.02	1.59	.180	[-.02, .09]

Note. Model = “Enter” method in SPSS Statistics; B = unstandardized regression coefficient; SE = standard error of the coefficient; *t* = t-value; *p* = p-value.

Table 25

Multiple Regression Results for Mid-Year Letter Naming Fluency (Kindergarten)

Variable	*B*	*SE*	*t*	*p*	95% CI
	Mid-Year Achievement on Letter Naming Fluency (In-Person Model)				
Constant	6.73	6.57	1.02	.314	[-6.68, 20.14]
Sex	5.95	4.15	1.43	.162	[-2.52, 14.41]
Individual Educational Program Status	10.17	7.17	1.42	.166	[-4.56, 24.80]
Socioeconomic Status	4.92	4.06	1.21	.234	[-3.36, 13.20]
Beginning Letter Naming Fluency Score	.70	.16	4.35	.001	[.37, 1.02]
Activities Completed	.07	.03	2.09	.045	[.002, .13]
	Mid-Year Achievement on Letter Naming Fluency (Virtual Model)				
Constant	10.74	5.87	1.83	.101	[-2.54, 24.02]
Sex	1.81	6.01	.30	.769	[-11.78, 15.42]
Socioeconomic Status	.60	6.25	.10	.926	[-13.54, 14.74]
Beginning Letter Naming Fluency Score	.80	.23	3.46	.007	[.28, 1.32]
Activities Completed	.004	.02	.158	.878	[-.05, .05]

Note. Model = "Enter" method in SPSS Statistics; B = unstandardized regression coefficient; SE = standard error of the coefficient; *t* = t-value; *p* = p-value.

Table 26

Multiple Regression Results for Mid-Year Reading Composite (Kindergarten)

Variable	*B*	*SE*	*t*	*p*	95% CI
	Mid-Year Achievement on Reading Composite Score (In-Person Model)				
Constant	50.74	17.85	2.84	.008	[14.34, 87.14]
Sex	22.34	11.24	1.99	.056	[-.59, 45, 27]
Individual Educational Program Status	-7.56	19.52	-.39	.701	[47.39, 32.26]
Socioeconomic Status	3.04	11.17	.27	.787	[119.74, 25.82]
Beginning Reading Composite Score	1.21	.20	6.01	<.001	[.80, 1.62]
Activities Completed	0.20	.09	2.29	.029	[.02, .37]
	Mid-Year Achievement on Reading Composite Score (Virtual Model)				
Constant	49.68	20.04	2.48	.035	[4.34, 95.02]
Sex	-9.61	20.77	-.46	.655	[-56.59, 37.38]
Socioeconomic Status	-7.74	22.50	-.34	.739	[58.64, 43.15]
Beginning Reading Composite Score	1.20	.49	2.43	.038	[.084, 2.31]
Activities Completed	0.11	.09	1.25	.242	[-.09, .30]

Note. Model = “Enter” method in SPSS Statistics; B = unstandardized regression coefficient; SE = standard error of the coefficient; *t* = t-value; *p* = p-value.

Although the beginning-of-the-year assessment set in kindergarten did not include a measure of letter-sound fluency, Nonsense Word Fluency - Correct Letter Sounds did measure this construct at the mid-year benchmark administration. For this regression model, sex, Individual Educational Program status, socioeconomic status, and letter naming fluency scores from the beginning of the year explained the outcomes on the mid-year Correct Letter Sounds score at a moderate level ($\Delta R^{2\,=}$ .734) for in-person learners. Total activities completed significantly impacted this model for this cohort, as shown in Table 27.

Table 27

Multiple Regression Results for Nonsense Word Fluency – Correct Letter Sounds (Kindergarten)

Variable	*B*	*SE*	*t*	*p*	95% CI
	Mid-year achievement on Nonsense Word Fluency - Correct Letter Sounds (In-Person Model)				
Constant	0.05	3.79	0.01	.989	[-7.68, 7.78]
Sex	8.83	2.39	3.69	<.001	[3.95, 13.71]
Individual Educational Program Status	-2.12	4.13	-0.51	.612	[-10.55, 6.32]
Socioeconomic Status	-0.36	2.34	-0.15	.879	[-5.13, 4.41]
Beginning Letter Naming Fluency Score	0.67	0.09	7.23	<.001	[0.48, 0.85]
Activities Completed	0.43	0.02	2.32	.027	[0.01, 0.08]
	Mid-Year Achievement on Nonsense Word Fluency – Correct Letter Sounds (Virtual Model)				
Constant	8.18	7.67	1.07	.314	[-9.17, 25.53]
Sex	-3.79	7.85	-0.48	.641	[-21.56, 13.98]
Socioeconomic Status	-0.46	8.16	-0.06	.957	[-18.93, 18.01]
Beginning Letter Naming Fluency Score	0.34	0.30	1.12	.290	[-0.34, 1.02)
Activities Completed	0.04	0.03	1.47	.176	[-0.02, 0.11]

The results of the multiple regression analyses for the first-grade cohort are displayed in Table 28 through Table 32. At this level, beginning scores on both Nonsense Word Fluency - Correct Letter Sounds (Tables 28 and 29) and Nonsense Word Fluency - Whole Words Read (Tables 30 and 31) contributed to the model at significant levels. The Activities Completed variable for Nonsense Word Fluency, Whole Words Read was not statistically significant. Table 32 displays the scores for middle of the year for the overall battery (Reading Composite), which were significantly explained by beginning of the year scores for the same measure for both in-person and virtual learners. Activities completed did not significantly impact the model.

Table 28

Multiple Regression Results for Nonsense Word Fluency – Correct Letter Sounds (First Grade)

Variable	*B*	*SE*	*t*	*p*	95% CI
	Mid-year achievement on Nonsense Word Fluency - Correct Letter Sounds (In-Person Model)				
Constant	11.65	11.19	1.04	.309	[-11.55, 34.84]
Sex	3.98	6.13	0.65	.523	[-8.73, 16.68]
Individual Educational Program Status	7.04	11.94	0.59	.562	[-17.73, 31.81]
Socioeconomic Status	3.61	6.23	0.58	.568	[-9.31, 16.54]
Beginning Nonsense Word Fluency - Correct Letter Sounds Score	1.24	0.24	5.28	.001	[.75, 1.73]
Activities Completed	0.03	0.04	0.80	.433	[-.05, .12]

Note. Model = "Enter" method in SPSS Statistics; B = unstandardized regression coefficient; SE = standard error of the coefficient; *t* = t-value; *p* = p-value.

Table 29

Multiple Regression Results for Nonsense Word Fluency – Correct Letter Sounds (First Grade)

Variable	*B*	*SE*	*t*	*p*	95% CI
	Mid-Year Achievement on Nonsense Word Fluency - Correct Letter Sounds (Virtual Model)				
Constant	38.71	8.24	4.70	<.001	[20.90, 56.52]
Sex	-11.10	6.32	-1.76	.103	[-24.75, 2.55}
Socioeconomic Status	-13.90	6.94	-2.00	.067	[-28.89, 1.10]
Beginning Nonsense Word Fluency - Correct Letter Sounds Score	0.93	0.14	6.68	<.001	[-.03, .10]
Activities Completed	0.04	0.03	1.23	.242	[.03, .10]

Note. Model = "Enter" method in SPSS Statistics; B = unstandardized regression coefficient; SE = standard error of the coefficient; *t* = t-value; *p* = p-value.

Table 30

Multiple Regression Results for Nonsense Word Fluency –Whole Words Read (First Grade)

Variable	*B*	*SE*	*t*	*p*	95% CI
	Mid-Year Achievement on Nonsense Word Fluency: Whole Words Read (In-Person Model)				
Constant	-2.11	5.30	-.40	.695	[-13.10, 8.89]
Sex	2.16	23.00	.73	.475	[-4.02, 8.34]
Individual Educational Program Status	-5.28	5.77	-.92	.370	[-17.25, 6.69]
Socioeconomic Status	1.13	3.14	.36	.723	[-.003, .09]
Beginning Nonsense Word Fluency, Whole Words Read Score	1.73	.42	4.09	.001	[.85, 2.61]
Activities Completed	0.04	0.02	1.95	.065	[-.003, .09]

Note. Model = "Enter" method in SPSS Statistics; B = unstandardized regression coefficient; SE = standard error of the coefficient; *t* = t-value; *p* = p-value.

Table 31

Multiple Regression Results for Nonsense Word Fluency –Whole Words Read (First Grade)

Variable	*B*	*SE*	*t*	*p*	95% CI
	Mid-Year Achievement on Nonsense Word Fluency: Whole Words Read (Virtual Model)				
Constant	16.94	5.20	3.26	.006	[5.72, 28.20]
Sex	-4.18	4.06	-1.03	.321	[-12.95, 4.58]
Socioeconomic Status	-11.08	4.61	-2.40	.032	[-21.04, -1.11]
Beginning Nonsense Word Fluency, Whole Words Read Score	1.16	.27	4.26	<.001	[.57, 1.74]
Activities Completed	0.01	0.02	0.77	.456	[-.03, .06]

Note. Model = "Enter" method in SPSS Statistics; B = unstandardized regression coefficient; SE = standard error of the coefficient; *t* = t-value; *p* = p-value.

Table 32

Multiple Regression Results for Mid-Year Reading Composite Scores (First Grade)

Variable	*B*	*SE*	*t*	*p*	95% CI
	Mid-Year Achievement on Reading Composite Score (In-Person Model)				
Constant	-26.13	48.07	-.54	.592	[-125.82, 73.56]
Sex	-8.78	21.26	-.39	.704	[-52.26, 35.91]
Individual Educational Program Status	30.69	44.89	.68	.501	[62.40, 123.78]
Socioeconomic Status	8.66	23.51	.37	.716	[-40.10, 57.41]
Beginning Reading Composite Score	1.60	.33	4.84	<.001	[.91, 2.28]
Activities Completed	-0.05	0.15	-0.34	.739	[-.35, .25]
	Mid-year achievement on Reading Composite Score (Virtual Model)				
Constant	13.76	35.92	.38	.708	[-63.84, 91.37]
Sex	-42.72	24.22	-1.76	.101	[-95.03, 9.60]
Socioeconomic Status	-24.72	26.79	-0.92	.373	[-82.59, 33.15]
Beginning Reading Composite Score	1.72	.26	6.53	<.001	[1.15, 2.29]
Activities Completed	0.10	0.12	0.85	.410	[-.15, .35]

Note. Model = "Enter" method in SPSS Statistics; B = unstandardized regression coefficient; SE = standard error of the coefficient; *t* = t-value; *p* = p-value.

CHAPTER 5: SUMMARY

While phonological awareness and working memory have been studied in other contexts, this study sought to examine the correlation of an online intervention directly focused on these skills with foundational reading achievement scores. As a wide range of applications are being deployed to support learning during the COVID-19 crisis (Crompton et al., 2021), it is critical to examine the effectiveness of such platforms. This chapter provides a summary of the study's findings as related to the research questions, as well as a discussion of implications for the current and future educational context, limitations, and recommendations for further research.

Summary and Discussion

The purpose of this study was to determine if completing activities in an online application specifically targeting phonological awareness and working memory would impact the foundational reading scores of kindergartners and first graders after nine weeks of participation. Further, the study examined the relationship of the number of activities completed with outcome scores for students learning both at school and remotely at home. Results revealed specific relationships for treatment groups.

This quasi-experimental study included 175 participants in kindergarten and first grade at one elementary school in Upstate New York. Of the 175 participants, 92 were enrolled in the kindergarten program, while 83 were enrolled in first grade. Of the 92 kindergartners, 14 participated in the school's virtual academy, while 18 of the 83 first graders were enrolled in this model. Progress was measured at the beginning of the year and at the middle of the year (following treatment) with the Acadience Reading measures. All recommended measures are reported to yield adequate reliability and validity, except for Phoneme Segmentation Fluency. As such, this measure was not analyzed separately, although this score is included in the overall Reading Composite Score at the middle of the year for kindergartners, as well as at the beginning of the year in first grade.

Multiple, independent t-tests were applied to compare the mean growth exhibited by students in the control and treatments groups to address the first research question. While higher mean growth was exhibited by kindergarten students in the treatment group for Letter Naming Fluency and first-grade students in the treatment group for Nonsense Word Fluency - Correct Letter Sounds, gains did not reach a significant level. It was intended for those in the treatment group to have a similar level of interaction with the platform, as the direction at the onset was for students to be logged in and working in the application for 15 minutes, four days per week. Upon analysis of the output data provided by Sound Reading, however, it was revealed that this objective was not consistently met. Implementing a new intervention in the uncertain and changing parameters of the 2019-2020 school year resulted in a wide variation in the time on-task for individual students. The range of completed activities across conditions was 20 to 560. Many factors impacted this scenario, including a shortage of staff members, technology and connectivity issues, and irregular student attendance.

The second research question, then, is useful when analyzing the results of the intervention. This question focused on the treatment groups, both in-person and virtual, at both grade levels. Multiple regression analysis was applied to determine the impact of the number of activities completed in relation to outcomes. Variables loaded into the model included sex, Individual Educational Program status, socioeconomic status, beginning scores (where applicable), and the number of activities completed. These factors explained each model at a significant model with the adjusted R^2 scores spanning from .38 to .78. In addition, the in-person treatment group was analyzed separately from the virtual learning group. As the presentation of instruction outside the intervention was much different for these discreet groups, they were not analyzed together.

In kindergarten, activities completed positively and significantly correlated with higher scores on Letter Naming Fluency at the mid-year benchmark for in-person learners (p =.045), indicating that students with higher completion rates in the Sound Reading application had higher scores on the Letter Naming Fluency measure. While students come into kindergarten with a range of fluency levels in letter naming, the growth in this skill, along with letter sound fluency, between the fall and spring of a child's kindergarten year is a critical indicator of later reading efficiency (Clemens, 2017). Letter sound fluency is measured at the mid-year point of kindergarten with the Nonsense Word Fluency - Correct Letter Sound assessment. Activities completed significantly impacted this model (p = .027) for the in-person group with the beginning Letter Naming Fluency score loaded as an independent variable. Overall, activities completed significantly impacted mid-year achievement on the Reading Composite Score in kindergarten for in-person learners (p = .029). Significance was not attained by the smaller cohort of virtual learners.

In first grade, none of the models were significantly impacted by the number of activities completed. This result may have been influenced by the decision to begin all first graders in the Hop, Skip, & Jump program due to perceived and documented gaps in phonemic awareness unique to this cohort. While the Acadience Reading measures are more heavily weighted in the application of phonemic awareness and phonics at the first-grade level, the activities in Hop, Skip, & Jump focus on skills measured more directly by the kindergarten Acadience measures. Although this decision seemed sound with the evidence the teachers had on the students in front of them, less effect may have been shown because of the distance between the skills practiced and the level of the assessment at this grade level.

Conclusion

This quantitative analysis of data provided by the treatment application, Sound Reading, and the scores on foundational reading measures, Acadience, revealed significant findings in the following areas:

1. The number of completed Sound Reading activities significantly added to the regression model to impact mid-year achievement on Letter Naming Fluency and Nonsense Word Fluency - Correct Letter Sounds for kindergarteners participating in the in-person learning model.
2. The number of completed Sound Reading activities significantly added to the regression model to impact mid-year achievement on Reading Composite scores for kindergartners learning in school.

Implications for Education

Theoretically, gaining better understanding of the effectiveness of online applications to support foundational reading skills has several implications for researchers. The use of technology will likely grow as a response to availability and environmental factors. This study provided evidence of significant gains from engagement in an online application for specific skills at the kindergarten level, including an increase in letter naming fluency. Online interventions to impact rapid naming have also had positive findings with older groups of students, however, the research on students at this early level is limited. As technological advances increase the attractiveness of online formats, it is essential that researchers continue to evaluate the learning potentials of such mediums, especially for the emergent reading population.

Results of this study indicate that gains in foundational skills can be made if the online intervention is closely aligned to the target skills. This has practical implications for educators and parents. With a plethora of online technologies available, careful selection must be employed when choosing materials to address student learning. In this study, an increase of task completion positively correlated with scores in kindergarten in rapid letter identification and the production of letter sounds, as well as the overall composite score at the mid-year point. While the software is available at a cost, no additional staff were needed to provide this intervention to students. Utilizing online applications, then, could support efficiency in the remediation of specific skills.

Limitations and Recommendations for Further Research

Future research into online applications to increase foundational reading skills is warranted. A major limitation of this study was the lack of a randomized control group. Due to the pandemic, the treatment and control groups were based on a capricious variable for a research study on foundational reading skills – the number of students allowed to ride a given school bus at one time as per local and state requirements. This constraint necessitated the formation of two cohorts, which were used as the treatment and control group. As such, the groups were not randomized. Descriptive statistics revealed that there was a discrepancy in students with Individualized Educational

Programs. In the kindergarten treatment group, 8.1% of the students had Individualized Educational Programs, while 19.5% of the control group had Individualized Educational Programs. In first grade, 7.1% of the treatment group and 10.8% of the control group had Individualized Educational Programs. This factor may have impacted the results, as students with disabilities may have benefitted from the intervention to a greater degree than students without documented disabilities. Further studies should carefully analyze impacts among such subgroups.

In addition, multiple regression was applied to analyze the activity completion levels of students with their outcome performances. Overall, however, activity completion levels were lower than expected. In kindergarten, only two students completed all 15 levels in Hop, Skip, & Jump. In first grade, only four students completed the Hop, Skip, & Jump program. According to Sound Reading Solutions, a block of 30 minutes is recommended for the program. This includes print-based activities. (Sound Reading Solutions, n.d.). This school already has a balanced reading program, including a phonemic awareness component. A boost in phonemic awareness and working memory practice during independent time, however, was desired. While gains in some areas were promising, greater gains may have been exhibited with more time devoted to the task.

Accurately identifying students who are at-risk early in their educational careers and determining the precise skills in which to remediate should be an area of great focus for researchers and practitioners. As children are starting to apply letter-sound associations to recode words, efficiency in these processes could have dramatic results for all readers, beginning at the earliest stages. While previous research analyzed the impact of working memory interventions at later developmental stages (Dentz et al., 2017; Holmes et al., 2015; Loosli et al., 2012), this study addresses this skill before insurmountable gaps are formed. In addition, working memory and phonological awareness work together to support word reading (Knoop-van Campen et al., 2018), and both of these skills are targeted within the treatment. Finally, the provision of such skill-based practice through a software-based application increases the integrity of the exercises, as well as the efficiency of the intervention. These concerns are at the forefront of the minds of early educators, as they have grappled with providing high-quality, effective interventions during the current pandemic crisis.

APPENDIX A: INSTITUTIONAL REVIEW BOARD APPROVAL

ST. JOHN'S UNIVERSITY

Federal Wide Assurance: FWA00009066

Dec 17, 2020 10:34:22 AM EST

PI: Antoinette Halliday
CO-PI: Clare Irwin
Dept: Education Specialties

Re: Initial - IRB-FY2021-196 *STRENGTHENING PHONOLOGICAL PROCESSING AND WORKING MEMORY TO SUPPORT EARLY READING ACQUISITION*

Dear Antoinette Halliday:

The St John's University Institutional Review Board has rendered the decision below for *STRENGTHENING PHONOLOGICAL PROCESSING AND WORKING MEMORY TO SUPPORT EARLY READING ACQUISITION*.

Decision: Exempt

PLEASE NOTE: If you have collected any data prior to this approval date, the data must be discarded.

Selected Category: Category 4. Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met:

(i) The identifiable private information or identifiable biospecimens are publicly available;

(ii) Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained directly or through identifiers linked to the subjects, the investigator does not contact the subjects, and the investigator will not re-identify subjects;

(iii) The research involves only information collection and analysis involving the investigator's use of identifiable health information when that use is regulated under 45 CFR parts 160 and 164, subparts A and E, for the purposes of "health care operations" or "research" as those terms are defined at 45 CFR 164.501 or for "public health activities and purposes" as described under 45 CFR 164.512(b); or

(iv) The research is conducted by, or on behalf of, a Federal department or agency using government-generated or government-collected information obtained for nonresearch activities, if the research generates identifiable private information that is or will be maintained on information technology that is subject to and in compliance with section 208(b) of the E-Government Act of 2002, 44 U.S.C. 3501 note, if all of the identifiable private information collected, used, or generated as part of the activity will be maintained in systems of records subject to the Privacy Act of 1974, 5 U.S.C. 552a, and, if applicable, the information used in the research was collected subject to the Paperwork Reduction Act of 1995, 44 U.S.C. 3501 et seq.

Sincerely,

Raymond DiGiuseppe, PhD, ABPP
Chair, Institutional Review Board
Professor of Psychology

Marie Nitopi, Ed.D.
IRB Coordinator

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