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To cite this article:

Chen, J. J., Kacerek, C. R., & Ruiz, M. (2023). The letter-naming benchmarks, growth profiles, and the efficacy of an interactive learning app on uppercase letter-name learning for preschool children. *International Journal of Technology in Education (IJTE)*, 6(1), 113-135. <https://doi.org/10.46328/ijte.360>

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The Letter-Naming Benchmarks, Growth Profiles, and the Efficacy of an Interactive Learning App on Uppercase Letter-Name Learning for Preschool Children

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Article Info

Article History

Received:

11 July 2022

Accepted:

10 November 2022

Keywords

Educational apps

Intervention study

Letter-name knowledge

Low-income backgrounds

Uppercase letters

Abstract

While mobile devices are becoming increasingly ubiquitous (even in low-income families in the United States) and are being used for educational purposes, it is unclear how these technological tools may benefit letter learning (a foundational precursor to early literacy achievement) in preschool children. To contribute clarity, this study tested the efficacy of an app intervention on letter learning. Participants consisted of 16 children (13 Hispanics and three African Americans) from two classrooms in a U.S. preschool serving children from low-income backgrounds. Using an experimental research design, the research team randomly assigned children to either the intervention condition (involving the use of an uppercase letter-matching game app on an iPad for 10 minutes daily in the classroom for five weeks) or the control condition. It was revealed that only a few children in either condition knew 10 or more uppercase letters on the pretest but most did meet this 10-letter benchmark and some even achieved or continued to achieve the 18-letter benchmark on the posttest, demonstrating varied growth in letter-name knowledge (LNK). Accordingly, the children's LNK evidenced the three profiles: (1) the "High Initial," (2) the "High Growth," and (3) the "Low Growth." Importantly, the paired sample t-test showed that the mean differences in gain of uppercase letters between the pretest and the posttest among children within the intervention condition was statistically significant, suggesting that the letter-learning app seemed effective for learning more uppercase letters. However, the two-sample t-test did not show significant mean differences in gain of uppercase letters between children in the two conditions.

Introduction

It is well recognized that the preschool years are an important period of rapid development and learning. During this time, an early yet critical developmental task for preschool children in the United States concerns the acquisition of alphabet knowledge (AK). AK is an umbrella construct broadly defined as an individual's ability to recognize and understand the letters in the English alphabet, including letter names, shapes, and sounds (National Early Literacy Panel, 2008; Piasta et al., 2022a; Roberts et al., 2018; Treiman, 2000). It is important for children to acquire AK early in order to learn to read in English. Yet, we only have limited knowledge of children's

AK acquisition and the ways in which such learning can be best strengthened (Piasta et al., 2022b). While support for the acquisition of AK has been provided through formal instruction in preschool classrooms, less is understood about how informal learning opportunities, such as those involving the use of mobile devices, might also serve as a source of support for letter learning. Notably, there exists a limited understanding of how mobile devices may benefit letter learning (a foundational precursor to early literacy achievement) among preschool children, despite their increasing ubiquity (even in low-income families in the United States) and popular use for educational purposes. To contribute knowledge to this area, the current study tested specifically the efficacy of a letter-learning app intervention on enhancing the uppercase letter-name knowledge of preschool children from low-income backgrounds.

Literature Review

The Importance of Alphabet Knowledge (AK)

The acquisition of AK is considered a watershed event in early and formal literacy acquisition because it serves as the bedrock of alphabetic reading and writing systems. Notably, as English is an alphabetic language, to achieve English proficiency for success in school and later in life, children in the United States must acquire early literacy, beginning with the acquisition of AK that lays the foundation for learning to read. Furthermore, AK is also an integral and foundational component of the broader alphabetic principle generally referred to as the awareness of the predictable, systematic relationship between written words and spoken sounds (i.e., printed words consisting of individual letters that represent discrete sounds of spoken language) (Huang et al., 2014). Thus, AK serves as a foundational building block of early literacy skills that children begin establishing during their preschool years to be better positioned for later literacy learning in kindergarten and beyond. In fact, it has been consistently documented that AK in preschool is one of the strongest predictors of emergent and later literacy achievement (e.g., Carr et al., 2020; Heilmann et al., 2018; Piasta et al., 2012a; Roberts et al., 2018).

The Importance of Letter-Name Knowledge (LNK)

It is widely established that AK consists of various integral components, especially letter names, shapes, and sounds. Despite their interrelationships, these elements are not all acquired simultaneously nor equally. Notably, letter names are generally learned before letter sounds by children in the United States in such a way that a child's acquisition of AK begins generally with letter-name knowledge (LNK), which in turn, serves as a foundational precursor to and a strong predictor of letter-sound knowledge (LSK) (Treiman et al., 2008; Worden & Boettcher, 1990). In the case of learning English, LNK is generally defined as knowledge of the letters in the English alphabet by their names, while LSK (i.e., grapheme–phoneme correspondence) by their associated sound(s) (Treiman et al., 2008; Worden & Boettcher, 1990). Not surprisingly, the letter-learning sequence that begins with LNK is also reflected accordingly in the children's early and frequent exposure to letter names in both informal instruction (e.g., caregiving in the home, games, songs) and formal instruction in school (Stahl, 2014).

Despite being developed first within AK, letter names are not all created equal and, thus, are not learned with equal speed and ease. Notably, certain letter names may be acquired by children faster and easier than others.

Specifically, much research has supported the own-name advantage in that children tend to learn the initial letter of their own name better than any other letter in the alphabet, a phenomenon that is likely attributable to early exposure and familiarity effects (e.g., Heilmann et al., 2018; Huang et al., 2014; Justice et al., 2006; Phillips et al., 2012; Treiman & Broderick, 1998; Treiman & Kessler, 2004). However, in a more recent study, Chen (2022) investigated letter-name knowledge among 12 preschool children from low-income and Spanish-speaking backgrounds, revealing little evidence for the own-name advantage but some evidence for the general name-advantage in that a few children could correctly identify the initial uppercase letter in some classmates' names. These findings suggest that letter learning is a complex phenomenon. It may be because the outcomes of letter learning are compounded by various factors, such as the nature of letter instruction and letter difficulty (Piasta et al., 2022b).

Letter-Name Learning: Uppercase Versus Lowercase

Letter-name learning does not appear to be a simple cognitive endeavor for young minds. There are various factors that can affect the process of letter-name learning, including the fact that each letter in the English alphabet is represented by two different graphic shapes: uppercase and lowercase. However, rather than learning both forms concurrently and equally, young children generally learn the names of uppercase letters before lowercase letters, thereby supporting the uppercase letter advantage (Chen, 2022; Worden & Boettcher, 1990). This phenomenon is potentially attributable to uppercase letters being taught early in the home as well as found in the child's literacy materials (e.g., alphabet books, games, toys) (Stahl, 2014; Worden & Boettcher, 1990). Furthermore, the learning of uppercase letters first has also been highlighted specifically in certain letter-naming goals (often known as benchmarks).

Letter-Naming Benchmarks

The importance of letter-name learning has become a major goal in early childhood, as reflected in standards formalized by state and federal documents and programs as well as advocated by professional organizations (e.g., the National Association for the Education of Young Children (NAEYC) and International Reading Association (IRA)). While there is a general consensus among these policy constituents that letter-name knowledge is critical for children to acquire in preschool years to promote their emergent and later literacy achievement, there remains a general lack of consensus or empirical rationale regarding appropriate preschool letter-naming benchmarks across the United States (Piasta et al., 2012). Specifically, in their review of state and federal standards in 2010, Piasta et al. (2012) found that at the state level, while some states set clear benchmarks requiring children to learn a certain number of target letters (uppercase, both uppercase and lowercase, or any), some others did not indicate such clear benchmarks. Among the 10 states in the United States that did specify clear letter-naming benchmarks, they all required children to recognize and name 10 or more letters (Piasta et al., 2012). In the state of New Jersey where the current intervention study was conducted, the letter-naming benchmark is vaguely specified in its latest "Preschool Teaching and Learning Standards" (developed in 2014) as requiring preschool children to know "many upper and lower case letters of the alphabet" (New Jersey State Department of Education, 2014, p. 48).

At the federal level, the Office of Head Start (2015) has adopted the benchmarks of naming 18 uppercase and 15 lowercase letters expected of children by 60 months of age. Furthermore, the Office of Head Start has also set for younger children (ages 48-60 months) the learning goal of identifying and naming “at least half of the letters [13] in the alphabet, including letters in own name (first name and last name), as well as letters encountered often in the environment” (p. 47). However, at the national and international level, IRA and NAEYC (1998) issued a joint position statement on “Learning to Read and Write: Developmentally Appropriate Practices for Young Children” where they did not specify a clear benchmark but only a general letter-learning goal for preschool children, which was to “identify some letters” (NAEYC, 1998, p. 15).

In addition to state and federal efforts, research has investigated letter-learning benchmarks. Specifically, empirical evidence (e.g., Invernizzi et al., 2004; Piasta et al., 2012) has substantiated that many preschool children in the United States are able to meet at least the 10-letter benchmark, knowing 10 or more letter names. For instance, Piasta et al. (2012) conducted a longitudinal study of 371 children enrolled in publicly funded preschools in the states of Virginia and Ohio by assessing their uppercase and lowercase letter-naming performances at the end of preschool and tracking their literacy outcome on three standardized measures at the end of first grade. These researchers found that the results favored the 10-letter benchmark by the end of preschool needed to potentially reach normal reading skills in first grade, but the optimal benchmarks of 18 uppercase and 15 lowercase letter names achieved in preschool would potentially help prevent later literacy difficulties in first grade.

Formal and Informal Instruction of LNK

Considering the importance of letter-naming ability in preschool for emergent and later literacy achievement, it is not surprising that letter-name learning has also been emphasized as a major learning goal for young children in various curricula and instructional approaches in many preschool and kindergarten classrooms. Notably, popular curriculum approaches to formal alphabet instruction vary from teaching letters beginning with those in the children’s names followed by those in words that are meaningful to them (e.g., the Creative Curriculum [Heroman et al., 2016]), to teaching letters in alphabetical order, usually one letter at a time (e.g., Open Court Reading PreK [SRA/McGraw-Hill 2003]).

Empirically, experimental studies have corroborated that focused, direct, or explicit instruction is key to children’s letter learning (e.g., Piasta et al., 2022b; Roberts et al., 2018). For instance, In their study of 83 preschool children (30 of whom dual language learners) from low-income backgrounds in six public preschool classrooms, Roberts et al. (2018) randomly assigned the children into one of four conditions (each with nine weeks of corresponding instruction): (1) experimental letter names only, (2) experimental letter sounds only, (3) experimental letter names and sounds, and (4) typical letter names and sounds. These researchers found that regardless of language status, children in the four groups made significant growth in alphabet learning from pretest to posttest. It was also evident that explicit instruction promoted learning the alphabet among at-risk and dual language learners and that experimental conditions leveraging three specific underlying cognitive learning processes were also proven beneficial. These findings attest to the beneficial effects of explicit instruction that taps into cognitive learning processes to support letter learning. Piasta et al. (2022b) further revealed the benefit of tailored instruction for

letter learning from their experimental study of 29 children (ages 3.5 years to 6.0 years), demonstrating that children, who received individualized instruction for target letters specific to their alphabet learning needs, tended to learn these letters better than control letters without such instruction. However, these researchers also revealed that letter difficulty existed for both conditions in that children tended to have difficulty learning more difficult letters irrespective of the status of these letters (target or control).

While targeted formal instruction (e.g., direct/explicit teaching) is considered a staple of education, informal instruction can also be a source of learning support. Yet, there is a limited understanding of how informal platforms might promote especially letter learning in young children. For instance, while emphasizing letter-name learning as a critical contributor to early literacy achievement, little is known about the impact of using applications (apps) on touch screen tablets to enhance children's early literacy learning (e.g., letter naming) (Neumann, 2014). Nonetheless, research has generally corroborated the educational benefits of using touchscreen mobile devices.

The Educational Benefits of Using Touchscreen Mobile Devices

Digital technologies in the forms of hardware (e.g., smartphones, tablets) and software (e.g., apps) have revolutionized the education landscape. Since Apple debuted its iPad in 2010, the entire world has increasingly drawn to this relatively novel kind of digital technology (i.e., touchscreen devices) for various functions, including running educational apps. As stated, Apple's App Store offers a myriad of education apps for all grade levels and subjects to run on the iPad. Thus, the iPad has justifiably gained increasing popularity as a mobile tablet for learning in the home and in the classroom (Aspiranti & Larwin, 2021; Hirsch-Pasek et al., 2015; Rideout, 2014, 2017).

The global interest in and popularization of interactive apps on touchscreen devices, especially the iPad, have subsequently compelled researchers to conduct meta-analyses and systematic reviews examining the potentiality of these new digital technologies for young children's learning, especially in certain domains (e.g., academic, cognitive, socio-emotional) (e.g., Griffith et al., 2020; Haßler et al., 2016; Hirsch-Pasek et al., 2015; Xie et al., 2018). For instance, Griffith et al. (2020) conducted a systematic review of 35 studies investigating the educational benefits of interactive apps on the learning of children younger than six years old. These researchers found that most of the studies comparing performances in math or language arts (e.g., letter naming and writing) between an intervention group of children using interactive apps and a control group of children engaging in equivalent classroom instruction indicated academic advantages of interactive apps for the intervention group. Similarly, Kim et al.'s (2021) meta-analysis of the effects of educational apps on literacy and math skills revealed positive outcomes for children in early grades, but these positive effects were larger in studies of preschool-aged children than those in higher grade levels (kindergarten-3rd grade). Collectively, the findings of these analyses suggest a learning advantage of interactive touchscreen technologies for young children, especially preschoolers.

There are good reasons why digital technologies may be particularly effective for supporting children's learning. From a developmental perspective, the multimodal interfaces and user-friendly functionality (e.g., relatively

intuitive, portable) of touchscreen mobile devices may particularly appeal to young children's natural penchant for hands-on tangibles to explore, learn, and engage in interactive activities (Cooper, 2005; Neumann, 2016). Particularly, touchscreen mobile devices have enhanced their functions to become more expansive including running interactive multimedia apps. These touchscreen tablets, in turn, have afforded multimodal interfaces (e.g., written texts, pictures, sounds), which do not require the kinds of fine-motor skills as do computer keyboards and mice; thus, they tend to appeal to young children's limited yet growing physical ability as well as their sensory needs (Flewitt et al., 2015; Kucirkova, 2014). Accordingly, touchscreen devices have become a valuable medium for early learning, thereby potentially helping to foster young children's learning motivation and engagement. It is not surprising then that children as young as two years old can independently use tablets for learning and exploration in various ways, such as drawing (Couse & Chen, 2010) and playing interactive educational games as well as reading e-books (Neumann, 2014).

Furthermore, interactive apps run on touchscreen tablets can promote young children's mastery of skills. Leveraging knowledge from the Science of Learning, both theoretical and empirical research has attested that interactive, educational apps afford opportunities for engaging children in the repeated and varied practice of skills by integrating specific learning concepts into interactive gameplay and other activities (e.g., Aspiranti & Larwin, 2021; Griffith et al., 2020; Hirsh-Paseket al., 2015). For example, educational apps can be individualized to the child's pace and provide the child opportunities to engage in "drill and practice" as a means to independently master target skills and concepts (Hirsh-Pasek et al., 2015; Kim et al., 2021; Neumann et al., 2017; Papadakis et al., 2018). Additionally, teachers may gather assessment data of children's learning from these apps (e.g., student scores on an educational game) to subsequently inform their decision making of instruction.

The Importance of Studying LNK in Preschool Children from Low-income Backgrounds

The focus on preschool children's letter learning is particularly critical because from a developmental perspective, research (e.g., Justice & Ezell 2001; Justice et al., 2005; Lonigan et al. 1999) has suggested that at this particular stage of their development, preschool children (especially those from low-income backgrounds with fewer educational resources and input for early learning) may have not yet fully mastered the entire 26 letters in the alphabet. There is a critical need to understand how the letter learning of particularly preschool children, especially those from low-income backgrounds who lag behind their mainstream peers, may be best supported.

It has been found that children from low-income backgrounds continue to lag behind their more affluent peers in early math and reading achievements (Reardon & Portilla, 2016) and especially in LNK (Robins et al., 2014). Based on their analysis of three large-scale nationally representative samples of kindergarten children (ages 5-6) in 1998, 2006, and 2010, Reardon and Portilla (2016) found that while disparities in school readiness (as indicated by math and reading achievements) reduced moderately from 1998 to 2010, especially between children from low- and high-income backgrounds and between White and Hispanic children, these between-group achievement gaps still persisted to exist. Early delays in acquiring AK among children from low-income families are a likely culprit underlying these later achievement gaps (National Early Literacy Panel, 2008). In fact, research evidence has attested that children from at-risk backgrounds (e.g., socioeconomically) know significantly fewer letters than

their more advantaged peers. For instance, based on the performances of early literacy tasks administered at the beginning of the school year to 2,161 4- to 5-year-old children from at-risk backgrounds (e.g., living in poverty, battling health or developmental issues), Justice et al. (2005) found that these children recognized, on average, only 7.2 letters. Similarly, in tracking the alphabet knowledge of 172 preschool children attending Head Start programs serving children from low-income backgrounds, Heilmann et al. (2018) found that most of them were able to name only fewer than 10 letters at the beginning of the school year and about one third of those with limited AK made substantial progress of mastering 10 or more letters at the end of the school year. These findings suggest that opportunities for learning letters are particularly critical to preschool children's acquisition of LNK.

The use of educational apps on touchscreen devices may be an important informal source of support for letter learning, especially considering that touchscreen devices appear to benefit children's developmental and physical capacities (Cooper, 2005; Neumann, 2016) and that educational apps benefit their learning (e.g., Griffith et al., 2020; Hirsch-Pasek et al., 2015; Xie et al., 2018). Furthermore, the appeal of digital technologies for learning may be buttressed by the fact that in the United States, nearly all children (even those from low-income backgrounds) own a touchscreen mobile device on which their parents may download free apps for them to use (Rideout., 2017). Considering that many apps offer the advantage of being readily accessible for minimal to no cost, which is particularly appealing to low-income families, they may serve as an important context for children's learning. The increasingly ubiquitous availability of apps for children, thus, makes it imperative that we continue to evaluate their educational benefits.

Premised on the power of digital technologies as a context for learning, the research team investigated the efficacy of an uppercase letter-matching game app using an iPad in improving uppercase letter- name knowledge (ULK) among preschool children from low-income backgrounds in the United States. In doing so, this study sought to provide an equitable educational intervention for helping these children learn the names of the letters in the alphabet, which is a critical developmental point of entry into acquiring early literacy. The findings could contribute to the growing knowledge in the appropriate leverage of digital technologies as a complementary and/or supplementary informal intervention for facilitating learning in children.

Constructivism as a Theoretical Framework

In addition to the aforementioned rationale for this study, this study was also guided by constructivist learning theories (e.g., Dewey, 1938; Piaget, 1936, 1957) suggesting that children learn best by doing and engaging in developmentally appropriate activities that are "hands-on" and "minds-on." Both the hands-on movement (e.g., sweeping and tapping on a touchscreen) and the minds-on learning engagement have also been promoted by the "Science of Learning" (Hirsch-Pasek et al., 2015). Thus, in this intervention study, the use of an app on an iPad for learning the uppercase letters in the alphabet aligns with the developmental, constructivist perspective, promoting children's active knowledge construction by naturally exploring learning using tangibles. The constructivist approach to leveraging apps on mobile devices as a source of learning and expression of understanding by children has also been supported by research (e.g., Couse & Chen, 2010; Neumann, 2014). However, not all apps are educationally beneficial. In fact, some are considered not developmentally appropriate

for young children and their educational materials lack quality (Sari et al., 2019). Additionally, the content of some apps is highly constrained to non-intellectually stimulating activities (e.g., tracing letters) (Quinn & Bliss, 2021). Thus, from a constructivist perspective, these apps may potentially lead to less robust interactive learning. In contrast, there may be interactive apps that can effectively support young children's learning of foundational early skills, such as letters in the alphabet.

The Goal of the Study

This study endeavored to investigate the efficacy of a letter-learning game app as an early intervention for improving preschool children's LNK. To this end, it was guided by the following research questions in reference to preschool children from low-income backgrounds:

- (1) What and how many uppercase letters do preschool children recognize on the pretest and posttest?**
 - a. How many of these preschool children achieve the 10-letter and the 18-letter benchmark?
 - b. What growth profiles in ULK do these children demonstrate?
- (2) Is the letter-matching game app effective for learning more uppercase letters?**
 - a. Is there a significant mean difference in gain of uppercase letters between the pretest and the posttest among the children within the intervention and the control condition?
 - b. Is there a significant mean difference in gain of uppercase letters from the pretest to posttest between the children in the intervention and the control condition?

Method

Research Design

This study was approved by the Institutional Review Board of the researchers' university. Upon approval, the research team applied Patton's (2015) purposeful criterion sampling technique to secure the participation of one preschool that met the criterion of serving children from low-income backgrounds in a northeastern state of the United States. This preschool followed the Creative Curriculum. According to Teaching Strategies, LLC. (n.d.), the Creative Curriculum is a developmentally appropriate curriculum that combines the rigor of academic content with the promotion of socio-emotional and cognitive development. Another criterion was that the participating children must have not yet fully mastered all the names of the 26 letters in the alphabet in order to determine the efficacy of the intervention for helping them learn more letters. Just as demonstrated by previous research (e.g., Justice & Ezell 2001; Justice et al., 2005), it is expected that developmentally, preschool children (especially those from low-income backgrounds) in the United States may have partial but not full knowledge of the English alphabet. Based on the criterion of children's letter mastery, two classrooms were recommended for participation by the preschool authority consenting to the research activity at the school. An introductory meeting with the parents/guardians was arranged by the preschool authority for the research team to recruit child participants via parental consent. During this meeting, the research team described orally and in writing, via an informed consent letter, the nature of the study and the children's participation including the procedures involved and their rights as participants. Respecting families who were Spanish-speaking, the research team provided each parent/guardian a detailed consent letter written in both English and Spanish. Additionally, the research team showed and explained

the letter-matching game app that the children in the intervention group would be using to learn letters.

Although 18 signed letters were received from parents consenting to their children’s participation in this study, due to the fact that one child moved to a non-participating classroom and another child lost interest in participation, the final sample consisted of only 16 children. For this intervention study, an experimental research design was employed. Specifically, the research team assigned the 16 children randomly to either the intervention or the control condition by drawing names out of a box.

Participants

The participating children came from two classrooms: five from Classroom A and 11 from Classroom B. As shown in Table 1, the eight children (ages 32-48 months, $M = 41$) in the intervention condition consisted of five girls and three boys, and the eight children (ages 34-44, $M = 39$) in the control group consisted of an equal number of girls (4) and boys (4). The children were all born in the United States. However, thirteen of the 16 children were from Hispanic, Spanish-speaking households, eight of whom spoke both Spanish and English. The remaining three participants were African Americans. This ethnic composition reflected that of the general child population at this particular preschool serving children from low-income backgrounds, most of whom were also from Hispanic, Spanish-speaking households.

Table 1. Sociodemographic Characteristics of Participating Children ($N = 16$)

Intervention Group ($n = 8$)				Control Group ($n = 8$)			
Child	Age	Gender	Ethnicity	Child	Age	Gender	Ethnicity
#1	38 months	Girl	Hispanic	#1	35 months	Boy	African American
#2	39 months	Girl	Hispanic	#2	44 months	Boy	Hispanic
#3	40 months	Boy	Hispanic	#3	34 months	Girl	Hispanic
#4	32 months	Girl	Hispanic	#4	36 months	Girl	Hispanic
#5	41 months	Boy	Hispanic	#5	38 months	Girl	Hispanic
#6	42 months	Girl	Hispanic	#6	39 months	Boy	Hispanic
#7	44 months	Girl	Hispanic	#7	40 months	Boy	African American
#8	48 months	Boy	African American	#8	42 months	Girl	Hispanic

Data Collection

Data was collected over the course of seven weeks, including a five-week intervention. To assess the efficacy of the intervention in enhancing children’s ULK in the intervention group in comparison to their counterparts in the control group, the research team collected both baseline and endline data from all participating children. Specifically, following the exact protocol, the research team administered to each child individually a pre-intervention uppercase letter recognition test (pretest, during the week before the intervention) as baseline data and a post-intervention uppercase letter recognition test (posttest, during the week after the intervention) as endline data so that these two sets of data may be compared within and between the two groups of children.

Procedures

The Uppercase Letter Recognition Test

The research team decided to focus only on the children's uppercase letter recognition performance because during the pretest, these children recognized virtually no lowercase letters, and only some uppercase letters. The attention on uppercase letters was also consistent with that of previous research (e.g., Justice et al., 2006; McBride-Chang, 1999) and with the general consensus that children tend to learn uppercase before lowercase letters (e.g., Justice et al., 2006; Worden & Boettcher, 1990). To avert the potential familiarity effect of the order of the alphabet (from A to Z) on the outcome, the research team randomly drew a letter one after another out of a box, which determined the order of each letter's appearance on the naming test. To ensure that all the 26 uppercase letters were legible and consistent in format, each letter was typed up in the same font style (Century Gothic) and large font size (300 points) on an individual screen using the PowerPoint program.

During the pretest and posttest, a researcher from the research team administered the test by showing the child one uppercase letter at a time as a stimulus on the screen of an iPad. The child was then instructed to name the target letter. If the child could not verbally name the letter, the researcher would ask the child to match it with a letter on the iPad keyboard by pointing to or pressing it. When ready to go from one letter to another, the researcher clicked the right arrow button on the keyboard to move to the next screen. Each pretest and posttest took the children between 5 and 15 minutes (averaging 8 minutes) to complete.

On a record sheet, the researcher indicated a checkmark next to each correctly identified letter (noting whether the child said the letter name or matched it with a letter on the keyboard), and the child's response next to each incorrectly named letter. Upon test completion, the researcher quantitatively tabulated the number of correctly recognized uppercase letters by each child. All of these data were then typed up in an Excel spreadsheet for later analysis.

The Uppercase Letter Learning Intervention

The letter learning app used for the intervention was Kangaroo Crew Loo-Loo's Alphabet Matching Game app, which was part of the "Kangaroo Crew: Help a Child Love to Read!" program (<http://www.kangaroocrew.com/>). The research team decided to test its efficacy because this app was described as introducing all 26 letters in the alphabet in an easily maneuverable matching game format accompanied by vibrant voiced messages and visual animations, all of which were designed to capture and sustain the interest, motivation, and engagement of toddlers and preschoolers learning the letters. Thus, the app design and content appeared to be developmentally appropriate. While the families and teachers were informed about the app, during the intervention period, they were not provided with the authorization information to download or utilize the app on their own because the research team intentionally sought to avoid the potential confounding effect of the app being used by the children outside the intervention, which would likely skew the research results.

The intervention involved engaging the child in the letter-matching game app on an iPad. Considering the age and

developmental level of preschool children as having possibly an effect on their engagement level and attention span, the research team provided each child in the intervention condition only 10 minutes to use the app around the same time each school day for five weeks. This particular amount of time involved is appropriate for the age group as confirmed by previous research. For instance, the 3-year-olds in Couse and Chen's (2010) study engaged in drawing on a tablet for an average of 13 minutes each time. Furthermore, each child in the intervention group used the device in a quiet area of his/her classroom independently after a researcher had set it up. While the researcher was on-hand to troubleshoot any technical issues or address questions from the child, evidently, the app was easy enough for the children to use and explore without much assistance.

Considering the children's low levels of ULK (as confirmed by the results of their uppercase letter recognition on the pretest), the research team decided to evaluate all of the intervention children on the Easy level. With the Easy level (just as with the Medium and Hard levels), there were five sublevels in increasing challenge (from the easiest level 1 to the hardest level 5). For the easiest level 1, the app would state the "goal" uppercase letter and the instruction [e.g., "Touch and say the letter B"] accompanied by a visual display of the letter on top and six large boxes (containing three correctly matched and three incorrectly matched letters). For the hardest level 5, the child was asked to listen only to the program's audio for the goal letter to match, devoid of a visual display of this goal letter. For all levels, if the child matched the uppercase letters incorrectly, the program would state the incorrect letter followed by an encouraging comment, such as "Not quite, try a different one." If the child matched the letter correctly, the program would restate the correctly selected letter, followed by a compliment such as, "Good job!" "You did it!" "Excellent!" or "Yippee!"

Data Analysis

To identify what and how many uppercase letters the children recognized on the pretest and posttest, the research team would examine the test results by listing the specific letters and adding up the number of letters identified. This analysis would also help ascertain the number of children achieving the 10-letter and the 18-letter benchmark as well as the profiles of their growth in ULK. Furthermore, two sets of statistical analyses would be performed to compare within and between group differences. First, to determine whether the letter-learning game app was effective in helping the children in the intervention condition improve their ULK, a paired t-test was performed, comparing the mean differences in uppercase letter recognition between the pretest and the posttest for the intervention group. Second, to evaluate whether there was a significant mean difference in the number of uppercase letters identified correctly from pretest to posttest between children in the intervention and the control condition, a two-sample t-test was conducted.

Results

Research Question #1: What and how many uppercase letters do preschool children recognize on the pretest and posttest?

A close examination of the specific letters recognized by all 16 participating children shows that only six of them were able to recognize the uppercase initial in their first name at the outset during the pretest. Furthermore, there

was a wide range of ULK from recognizing 0 to 14 letters ($M = 6.88$, $SD = 5.44$) on the pretest and 4 to 26 letters ($M = 15.25$, $SD = 6.92$) on the posttest among the children in the intervention group (see Table 2).

Table 2. Descriptive Statistics of Pretest, Posttest, and Gain Scores

	Intervention Group ($n = 8$)			Control Group ($n = 8$)		
	Mean	SD	Range	Mean	SD	Range
Pretest	6.88	5.44	0-14	9.13	10.23	0-22
Posttest	15.25	6.92	4-26	13.38	8.37	2-24
Gain	8.38	5.40	1-16	4.25	5.15	-2-14

Similarly, the number of uppercase letters identified by those in the control group ranged from 0 to 22 letters ($M = 9.13$, $SD = 10.23$) on the pretest and 2 to 24 letters ($M = 13.38$, $SD = 8.37$) on the posttest (see Table 2). As shown in Table 2, the average gain from pretest to posttest for the intervention group ($M = 8.38$, $SD = 5.40$) appears to be higher than that for the control group ($M = 4.25$, $SD = 5.15$).

Figure 1 shows the pretest and posttest results on uppercase letter recognition for both the intervention and the control group. As shown, from the pretest to posttest, there was an increased percentage of children in the intervention condition in naming the majority of the uppercase letters (21 letters: A, B, C, D, E, F, H, I, J, K, L, M, N, O, Q, T, U, W, X, Y, and Z). However, there was a decreased percentage of children in the intervention condition in recognizing the other five uppercase letters (G, P, R, S, and V). As for the control condition, although there was an increased percentage of children in recognizing six more uppercase letters (G, I, L, P, R, and V), they still could not name as many uppercase letters as the children in the intervention condition.

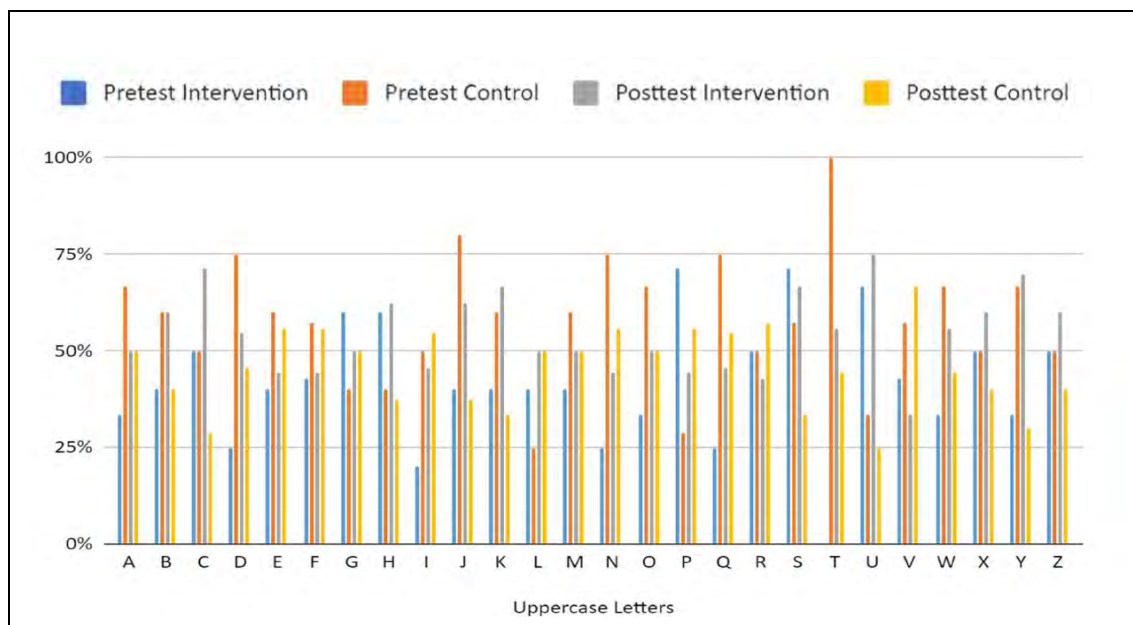


Figure 1. Percentages of Children in the Intervention Condition ($n = 8$) and the Control Condition ($n = 8$) Correctly Named Each Individual Uppercase Letter on the Pretest and Posttest

Research Question #1a: How many of these preschool children achieve the 10-letter and the 18-letter benchmark?

As presented in Table 3, in the intervention group, only three of the eight children met the 10-letter benchmark on the pretest, but nearly all (six of the eight) achieved the 10-letter benchmark on the posttest, of whom three also met the 18-letter benchmark. In the control group, the same three children who met the 10-letter benchmark actually also achieved the 18-letter benchmark on the pretest, and nearly all (five of the eight) achieved the 10-letter benchmark on the posttest, of whom four also met the 18-letter benchmark.

Table 3. Pretest and Posttest Scores of the Number of Uppercase Letters Recognized by Children ($N = 16$)

Intervention Group ($n = 8$)				Control Group ($n = 8$)			
Child	Pretest	Posttest	Gain*	Child	Pretest	Posttest	Gain*
#1	11	15	4	#1	1	8	7
#2	0	7	7	#2	1	4	3
#3	1	17	16	#3	20	20	0
#4	5	18	13	#4	2	10	8
#5	3	4	1	#5	0	2	2
#6	8	19	11	#6	22	24	2
#7	14	26	12	#7	22	20	-2
#8	13	16	3	#8	5	19	14

Note. Bolded child #s were from Classroom A and the rest from Classroom B.

*Gain is calculated by the difference in scores from pretest to posttest.

Research Question #1b: What growth profiles in ULK do these children demonstrate?

To determine the profiles of growth in LNK among children in the intervention and the control group, the research team followed Heilmann et al.'s (2018) identification of the three categories from their study of letter learning among socioeconomically disadvantaged preschool children attending Head Start programs during the fall and spring of their first school year. These categories were described as: (1) the “*High Initial*” group consisting of children who could name 10 or more letters in fall as well as in spring; (2) the “*High Growth*” group comprising those who did not reach the 10-letter benchmark in fall but did so successfully in spring; and (3) the “*Low Growth*” group representing those who did not achieve the 10-letter benchmark in either fall or spring (Heilmann et al., 2018).

Using these categories and based on the pretest and posttest scores (see Table 3) as conceptually similar to the fall and spring scores in Heilmann et al.'s study, three of the eight children in the intervention or the control condition would be considered in the *High Initial* group; three of the eight children in the intervention condition and two of the eight children in the control condition would fit the *High Growth* group; and two of the eight children in the intervention condition and three of the eight children in the control condition would be situated in the *Low Growth* group.

Research Question #2: Is the letter-matching game app effective for learning more uppercase letters?

The result of a paired sample t-test shows that the mean gain in uppercase letters recognized between the pretest ($M = 6.88$, $SD = 5.44$) and the posttest ($M = 15.25$, $SD = 6.92$) for the eight children within the intervention condition was statistically significant [$t(7) = 4.39$, $p = 0.003$]. A 95% confidence interval concerning the mean number of uppercase letter gains was between 3.86 and 12.89. Cohen's d was 1.33, further indicating that the magnitude of the difference was considerably large between the pretest and posttest results. A Cohen's d that is equal to or greater than 1.20 is considered "very large" (Sawilowsky, 2009). Thus, the result provided evidence that the letter-learning game app was effective in contributing to the children's ability to recognize more uppercase letters.

Research Question #2a: Is there a significant mean difference in gain of uppercase letters between the pretest and the posttest among the children within the intervention and the control condition?

The aforementioned result demonstrates that there was a significant mean difference in gain of uppercase letters between the pretest and posttest among the children within the intervention condition. In contrast, the result of a paired sample t-test showed that the mean gain in uppercase letters recognized between the pretest ($M = 9.13$, $SD = 10.23$) and the posttest ($M = 13.38$, $SD = 8.37$) for the eight children in the control condition was not statistically significant [$t(7) = 2.34$, $p > 0.05$]. This result may also suggest that the intervention was better than no intervention in helping children learn more uppercase letters.

Research Question #2b: Is there a significant mean difference in gain of uppercase letters from the pretest to posttest between the children in the intervention and the control condition?

A visual inspection of Figure 1 shows that children in the intervention group seemed to have more uppercase letter gains than their counterparts in the control group. However, the result of a two-sample t-test revealed that the mean difference in the overall gain of uppercase letters recognized correctly from pretest to posttest between the eight children in the intervention condition ($M = 8.38$, $SD = 5.40$) and the eight children in the control condition ($M = 4.25$, $SD = 5.15$) was not statistically significant ($t(14) = 1.56$, $p = 0.14$). This result suggests that from pretest to posttest, on average, the children in the intervention group did not recognize significantly more uppercase letters than their peers in the control group.

Discussion

Previous research (e.g., Treiman et al., 1996; Worden & Boettcher, 1990) has documented the critical importance of LNK in early literacy success, and educational policy documents in the United States (e.g., Office of Head Start, 2015) have also addressed this importance by prioritizing LNK as a learning goal in early literacy instruction in preschool. While various curriculum approaches to preschool letter learning have been adopted across the United States (Justice et al., 2006), little is known about what and how interactive digital apps may be a developmentally appropriate and effective means for facilitating such learning in preschool children. This

intervention study tested the efficacy of an interactive letter-matching game app on an iPad for supporting letter learning among children from low-income backgrounds. It revealed both expected and unexpected findings.

Uppercase Letters Recognized

Unexpectedly, contrary to the theory that children recognize the initial letter of their own name more readily than any other letter in the alphabet (Huang et al., 2014; Justice et al., 2006; Phillips et al., 2012; Treiman & Broderick, 1998), this study revealed that only six out of the 16 participating preschool children could identify the uppercase letter in the initial letter of their first name during the pretest. This finding is surprising also because it does not align with the formal instruction inherent in the Creative Curriculum (followed by the participating preschool) that teaches letters beginning with those in the children's names. This unexpected finding may be explained by the possibility that some letters in the children's names had not yet been formally taught to them at the time of this study. The finding is also not consistent with that of Robins et al.'s (2014) study revealing that low-income families tended to associate letters with the child's name in their letter conversations. It is plausible that the families of some of the children in this study might not have purposefully introduced or emphasized the letters in the child's name when talking to or teaching the child.

Comparative results between the pretest and the posttest revealed that while there was an increased percentage of children in the intervention group who could recognize the majority of the uppercase letters correctly, there was a decreased percentage of children who could identify the other uppercase letters. Theoretically, if a child knew a letter on the pretest, he/she should continue to know it on the posttest, especially when it was supposedly being reinforced by the intervention. However, this theory did not hold true in practice for some children who could not recognize five previously known uppercase letters, a finding that suggests an anomaly. It is possible that some children might have identified these letters on the pretest by random guessing. It is also plausible that these children's associative memory or knowledge of these letters might not have been strong enough to facilitate their continued recognition. Furthermore, there may also be idiosyncratic characteristics (e.g., cognitive and perceptual abilities, motivation, engagement) and unique contextual experiences (e.g., exposure to informal letter learning) influencing the children's ability to recognize letters (Stahl, 2014; Worden & Boettcher, 1990), making certain letters easier and others harder for some children to learn and remember. Future research might explore these possibilities by examining potential idiosyncratic and contextual influences on letter learning or analyzing longitudinally individual children's letter-naming performances over time.

The 10-Letter and 18-Letter Benchmarks Achieved

In the United States, across federal, state, and professional standards, there is little uniformity in determining benchmarks of letter-name learning in preschool (Piasta et al., 2012). In New Jersey where this study was conducted, the benchmark of knowing "many upper and lower case letters of the alphabet" set for preschool children appears ambiguous (New Jersey State Department of Education, 2014, p. 48). Nonetheless, Piasta et al.'s (2012) empirical finding suggested that the 10-letter benchmark, requiring children to know 10 or more letter names by the end of preschool, would be critical for achieving normal reading skills in first grade, but it would

be even more optimal for children to achieve the benchmarks of 18 uppercase and 15 lowercase letter names to prevent later literacy difficulties in first grade. In this study, although there were only a few children meeting the 10-letter benchmark initially on the pretest in both intervention and control groups, the majority of them in both groups did achieve the 10-letter benchmark and some even met the 18-letter benchmark on the pretest or both the pretest and posttest. This finding aligns with that of Heilmann et al.'s (2018) study demonstrating that most of the preschool children could name only fewer than 10 letters at the beginning of the school year and about one third of those with limited AK improved in mastering 10 or more letters at the end of the school year. Furthermore, this study also revealed that with respect to pretest performances, children in the intervention group and those in the control group recognized, on average, only 6.88 and 9.13 uppercase letters, respectively. This finding is similar to that of Justice et al.'s (2005) study of 2,161 preschool children from at-risk backgrounds, including living in poverty, uncovering that these children averaged only 7.2 letters in recognition at the beginning of the school year.

The benchmark-related findings suggest that formal instruction and informal instruction (e.g., the intervention) are likely contributors to the children's progress in LNK over the course of seven weeks during this study. For those children who did not meet the 10-letter or the 18-letter benchmark, explicit formal instruction and even formal or informal intervention focusing on learning the uppercase letters may be particularly beneficial to improving their LNK. Setting or following a developmentally appropriate benchmark of letter learning may also help guide early identification as well as prevention of reading difficulties in young children (Heilmann et al., 2018).

Profiles of Children's Growth in ULK

As demonstrated by the results, according to Heilmann et al.'s (2018) three profiles of growth in LNK, there appeared to be a nearly equal representation of children in each profile for both intervention and control conditions. This finding suggests there is heterogeneity of LNK within a relatively homogenous group of children from similar sociodemographic backgrounds. It is plausible that these children might have possessed varied letter learning experiences and needs. Thus, instruction (formal or informal) would need to attend to differences in children's LNK. While targeted, direct, or explicit instruction may benefit young children's letter learning, tailored instruction that scaffolds their achievement of stronger LNK by considering their learning strengths and needs as well as letter difficulty would be particularly productive (e.g., Piasta et al., 2022b; Roberts et al., 2018).

The Efficacy of the Letter-learning Game App for Children in the Intervention Condition

The findings seem to partially confirm that the letter-learning game app was effective in helping children in the intervention condition recognize more uppercase letters from the pretest to posttest. It may be because unlike some other apps that are highly constrained in content (e.g., tracing letters) to allow for active and interactive learning (e.g., Quinn & Bliss, 2021; Sari et al., 2019), the app used in this study was developmentally appropriate and constructivist-oriented by individualizing to the child's pace and providing the child the independence to practice target skills (i.e., learning uppercase letter names). This type of experience is considered beneficial to children's learning (Hirsh-Pasek et al., 2015; Kim et al., 2021; Neumann et al., 2017; Papadakis et al., 2018).

Furthermore, the finding of the favorable effect of the intervention on children's letter-name learning corroborates that of previous studies reviewed and analyzed by researchers (e.g., Griffith et al., 2020; Hirsch-Pasek et al., 2015; Xie et al., 2018), attesting to the educational benefits of apps. It also aligns with NAEYC & FRC's (2012) recommendation concerning identifying and incorporating interactive digital technologies and media in developmentally appropriate ways to benefit the learning of young children.

Non-significant Differences in ULK between the Intervention and the Control Condition

A surprising finding was that on average, children in the intervention group did not recognize significantly more uppercase letters from the pretest to the posttest than their counterparts in the control group. Thus, this finding did not support the efficacy of the letter-learning game app. It may be interpreted from two perspectives: (1) children's pretest performance, and (2) informal letter learning. First, according to the pretest data, there were three children in the control condition who already knew nearly all of the names of the uppercase letters in the alphabet (20 or more), whereas the highest numbers of uppercase letters known by the children in the intervention condition were only 14 (by one child) followed by 13 (by one child) and 11 (by one child). These data appear to suggest that some children in the intervention group might have already lagged behind some others in the control group in ULK. While the intervention appeared to have helped children learn more uppercase letters, the rate of their learning might still not have been fast enough to catch up to or surpass some of their more advanced counterparts in the control group.

Second, although both the control and the intervention group shared the same formal instruction of letter learning in their respective classrooms, it is unclear the extent to which the children in each group might have been exposed to informal letter learning at home, a factor that might have made a difference. That is, even though children in the control group did not partake in the intervention, some of them might have had more enriched informal letter-learning opportunities perhaps in the home. This conjecture is within the realm of possibility as research evidence has indicated that the learning of uppercase letters is enhanced by opportunities provided by the literacy environment in the home (e.g., intentional teaching by parents, letters found in toys and books) (Stahl, 2014; Worden & Boettcher, 1990).

Limitations of the Study and Directions for Future Research

This study reveals some methodological limitations that may be addressed in future investigations of letter learning. We highlight a few major ones here. First, as an exploratory study, the sample size was inherently small. Furthermore, it focused purposefully on children in one preschool educating those from low-income backgrounds. Thus, the findings lack generalizability to the broad and dissimilar populations. Future investigations might include a larger sample of children from different sociodemographic backgrounds and preschool contexts.

Second, the randomness of assigning children to one of two conditions rather than matching them up evenly or close to evenly according to certain characteristics (e.g., age, gender, level of ULK) might have affected the results. For instance, the lack of statistical significance in gain of uppercase letters from the pretest to posttest

between the intervention and the control group might have been due to the small sample size and the non-matching nature of participants.

Third, another limitation was that the research team pre-assessed each child's uppercase letter knowledge with a single letter recognition task created on an iPad. Future research might use multiple letter recognition tasks to assess and ensure the consistency of the child's ULK. Relatedly, based on the results of multiple assessments, one may select children with similar levels of letter recognition to assign to the two different experimental conditions so that they may be more comparable from an equal footing standpoint and that the efficacy of the intervention may be more salient.

Fourth, during both pretest and posttest tasks, a researcher asked the child to simply respond to each letter stimulus by verbalizing the name of the letter or physically pointing to/pressing a matching letter on the keyboard of the iPad used for the test. However, during the intervention, the child responded by touching the screen to match the correct letter(s) to the visually displayed goal letter. The discrepancy in letter recognition response between the test condition and the intervention activity might have influenced the results, as the verbal skill (naming the letter) and physical action (touching the screen to match the letter) tend to require different cognitive and physical capacities. Future experimental studies in this area should consider matching the test condition and the intervention condition more closely.

Fifth, another limitation of this study is related to the factors not captured or controlled in the statistical analyses. For instance, it is unclear whether the nature of classroom instruction following the Creative Curriculum, informal learning experiences (e.g., in the home), affective factors (e.g., interest, motivation), and developmental characteristics (e.g., age, ability) might have affected the cognitive process (e.g., attention, perception, memory) of letter learning across the children. Given the demands of teaching and parental responsibilities, the research team was unable to inquire the parents about their home literacy environment and the teachers about their letter instruction in the classroom and the learning abilities of the children. Such knowledge might have added clarity to the findings. Future research should consider including these contextual factors to render a clearer picture of potential influences on the children's letter recognition outcomes. Despite its methodological limitations, this intervention study reveals insights that can inform educational practices concerning the utility of interactive apps as a potentially valuable tool for facilitating young children's early literacy learning.

Educational Implications

As early childhood educators continue to seek effective pedagogical strategies to help children acquire AK, this study focusing on ULK offers important considerations for a developmental approach to informal and formal instruction. Three implications for educational practices are particularly noteworthy.

First, while the children in this study were all from low-income backgrounds, they demonstrated various developmental levels of ULK. Thus, assessing children's ULK should be conducted before engaging in any targeted instructional planning and practice. This kind of assessment would inform the formulation and

implementation of developmentally appropriate instruction that can support the children's individual needs (Chen, 2022). Post-instruction assessments should also be incorporated to determine the efficacy of a given instructional method. Furthermore, knowledge of a specific letter-learning benchmark or the development of such a benchmark may help guide early identification and intervention of reading difficulties in young children (Heilmann et al., 2018).

Second, utilizing digital technologies, by no means, should supplant formal instruction, but it could serve as a valuable supplementary and/or complementary tool for individualizing learning experience for children by building on a strengths-based model (i.e., capitalizing on the children's strengths as a means to address their unique needs). For instance, the letter-matching game app allows the child to learn at one's own individual pace and challenge level. Thus, integrating digital technologies in formal instruction can create effective individualized learning experiences for young children. Such informal yet individualized learning does not just enhance these children's early literacy skills but also helps them to begin building technological skills highly demanded for success in this digital era. Furthermore, teachers might consider differentiating instruction that could tap into the children's existing schema. Differentiated instruction could be designed for small groups of children according to their prior alphabet knowledge and current learning needs (Stahl, 2014). For instance, pedagogical strategies may include scaffolding children in progressing from letters commonly known to them as a starting point toward learning unfamiliar letters.

Third, effective integration of technology in the classroom has been found to facilitate young children's learning and development, especially among racial/ethnic minority and socioeconomically disadvantaged children. For instance, in their quasi-experimental, longitudinal study of 208 socioeconomically disadvantaged, and predominantly African-American preschoolers in 14 Head Start classrooms (7 serving as the computer intervention sites where children were given 15 minutes daily, as part of the curriculum, to play with developmentally appropriate interactive educational programs on the computer and 7 as the non-computer control sites), Janisse et al. (2018) found that over time, children in the computer condition demonstrated significantly greater gains in cognitive development than their counterparts in the control condition. Just like the use of an letter-matching game app in this interventions study as an informal opportunity for uppercase letter learning, an intentional integration of developmentally appropriate digital technologies for use by young children, especially those from low-income backgrounds who lack the exposure to or proper use of these technological tools for educational purposes, may help them learn.

Acknowledgements

This study was supported by a Students Partnering with Faculty research award from Kean University. We are grateful to Lois Mancuso, Paul Becker, Max Becker, and Robin Barkley for introducing the app to us and encouraging us to test it out. In particular, Lois connected us to the research site and served as our biggest cheerleader throughout the research process. We would also like to thank the preschool authority and educators at the research site for welcoming us and the parents and their children for their participation in this study.

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