The influence of mobile technologies on preschool and elementary children's literacy achievement: A systematic review spanning 2007-2019

Abstract

The presence of mobile technologies within preschool and elementary classrooms has been increasing, yet review studies which measure the effectiveness of mobile technologies to support children's literacy achievement remains scarce. The purpose of this study is to conduct a systematic review to examine the influence of mobile technologies on pre-kindergarten—5th grade students' literacy achievement between 2007 and 2019. Findings are reported according to study characteristics, followed by the patterns and trends related to achievement within and across literacy domains (phonics, phonemic awareness, fluency, vocabulary, comprehension, writing). We provide mobile device and app use strategies for teachers, while mapping clear research pathways for educational researchers and digital designers, with the ultimate goal of advancing the use of mobile technology to improve children's literacy achievement.

Mobile technologies, such as the iPad and other tablets, are widely used in public schools across the United States, where there is at least one device for every five students (Herold, 2016). With the increasing adoption and use of mobile devices in schools, most researchers are reporting positive educational outcomes (Hsin, Li, & Tsai, 2014; Wu et al., 2012). Affordances such as flexibility, accessibility, interactivity, and motivation and engagement (Liu, Navarrete & Wivagg, 2014) enable mobile technologies to function as a conduit for participation and learning (Green, 2019). Moreover, the features of mobile devices allow for learning mobility that desktop computers simply cannot offer. In fact, mobile touchscreen devices have been shown to support a variety of students engaged in the process of writing and reading due to their interactive and adaptive features (Cordero, Nussbaum, Ibaseta, Otaíza, & Chiuminatto, 2018). Bedesem and

Arner (2019) contend the most promising research involving mobile technologies in K-12 education includes simulations and the use of assistive technologies to benefit a wide range of learners, such as English Learners (ELs). They recognize that although mobile technology remains an emerging area of research, more research is needed to measure how mobile technologies impact student engagement, differentiation, and learning outcomes. Since the introduction of educational technology in schools, more research is needed to identify key patterns to determine the influence and future use of technology to support literacy.

Despite the paucity of knowledge regarding the impact of these devices on students' literacy achievement, Herold (2016) reported that public schools in the U.S. spend more than $3 billion dollars each year to purchase software programs, subscriptions to education platforms and content, as well as online assessments. Device adoption in schools varies widely. Districts purchase an array of cloud-based and software programs each year in an attempt to meet the diverse needs of their students (Bulman & Fairlie, 2016). Although no causation between device adoption and student achievement can be linked to mobile technology use, it is worth noting that the 2016 National Association of Educational Progress report on the achievement trends of 9, 13, and 17-year old students' show an increase in reading scores among all ages in 2004, 2008, and 2012 (Kena et al., 2016). This illustrates a potential assumption among schools that purchasing more advanced technology may lead to an increase in students' literacy performance.

Even with growing budgets allocated to the acquisition of technology devices and software in schools, a collective understanding of the impact of mobile devices on students' literacy achievement remains unknown. Therefore, it is essential to apply a critique of the conducted studies which involve the use of mobile technologies and applications (apps). The purpose of this research is to conduct a systematic review to examine the impact of mobile technologies on PK-5 (pre-kindergarten—5th grade) students' literacy outcomes between 2007-

2019. A systematic review helps "researchers identify, select and appraise all of the studies of a previously agreed level of quality that are relevant to a particular question" (Booth, Sutton, & Papaioannou, 2016, p. 3). By evaluating the studies which have investigated the impact of mobile technology on literacy achievement, our review serves to fill the current void by answering one broad question to identify key patterns and establish a foundation for future research.

Findings and Limitations of Previous Reviews

There are a limited number of review studies that have examined the impact of mobile technologies on early childhood and elementary children's literacy achievement within a school context. Related studies have analyzed the impact of educational technology on students' reading and writing (Cheung & Slavin, 2012; Wollscheid, Sjaastad, & Tømte, 2016), the influence of student and teacher characteristics on technology use (Burden, Kearney, Schuck, & Hall, 2019; Hsin et al., 2014; Tondeur, van Braak, Ertmer, & Ottenbreit-Leftwich, 2017), and the broader impacts of using mobile technology to support classroom learning (Fu & Hwang, 2018; Haßler, Major & Hennessey, 2016; Papadakis et. al., 2018; Wu et al., 2012; Zucker, Moody, & McKenna, 2009).

Impact of educational technology on students' reading and writing. Most similar to our study's purpose of using mobile technology to support literacy, only one systematic review was retrievable that studied the effectiveness of educational technology on reading outcomes. Cheung and Slavin (2012) examined research on the impact of technology use on reading achievement in K-12 classrooms. The review encompassed 84 studies for the final analysis. The findings suggest that educational technology generally produced a positive, though small, effect in comparison with traditional methods. The researchers noted that programs consistently used in classrooms fail to produce meaningful effects; however, positive outcomes were achieved when

innovative apps were used in conjunction with teachers' professional development. Though Cheung and Slavin's (2012) review offered marginal support for integrating educational technology into K-12 education, their study was focused on the broad impact of educational technology in K-12 classrooms and did not investigate the impact of mobile technology.

With regard to writing, we identified one review that measured the impact of digital devices and traditional pen and paper on elementary students' writing skills (Wollscheid, Sjaastad, & Tømte, 2016). Though their review was limited by an analysis of 10 included studies, researchers arrived at the following conclusions: a) handwriting led to improved writing skills over keyboarding, b) theoretical perspectives included cognitive psychology, neuroscience and learning, socio-cultural, and c) methodological flaws, such as limited sample size among quantitative studies, lack of nesting effects, and inadequately controlling for children's writing experience (Wollscheid et. al., 2016).

Influence of student and teacher characteristics on technology use. With a greater focus on the individual characteristics of students and teachers, Hsin and colleagues' (2014) conducted a systematic review to investigate the impact of technology use on young children's learning, and reported primarily positive outcomes. Their systematic review contained 87 studies spanning 2003-2013, but the focus was on students' cognitive development. For example, the authors identified that technology was a mechanism for students to increase peer collaboration. Hsin and colleagues' (2014) also revealed important technology integration considerations such as the child's individual characteristics (e.g., age, experience, time, gender), technology aspects (e.g., design, pedagogical approaches, content), and adults as a mediator (e.g., facilitators of engagement, adapting teaching, perceptions).

Burden et al. (2019) studied the extent to which mobile technology uses and teachers' innovative pedagogies were disruptive to the current school practices by developing a spectrum

rating scale. This scale ranged from innovative practices that *sustained* current practices but used mobile technologies to *disrupt* innovative practices. Disruptive practices included altering existing approaches and practices, such as the relationship between teachers and students, to enable learning with a mobile device. They examined 57 studies across K-12 settings and found only three empirical studies met their criteria for innovation; the highest level of innovation aimed to disrupt current pedagogical paradigms where student agency was a parameter (Burden et. al., 2019).

Another review study focused on the relationship between teachers' pedagogical beliefs and their educational uses of technology. Tondeur and colleagues' (2017) analyzed 14 qualitative studies from 2002 to 2012 via systematic review using a meta-aggregative approach. Findings highlight that technology integration can alter teachers' belief systems to become more student-centered and constructivist. Therefore, technology became a tool to motivate teachers to take risks and explore new pedagogical approaches.

Broader impacts of using mobile technology to support classroom learning. Of the few systematic reviews that have investigated the use of mobile technologies to support classroom learning, scholars have broadly investigated the collaborative nature of students learning with technology (Fu & Hwang, 2018) or focused too narrowly on the use of one technology device (Haßler, Major & Hennessey, 2016). Haßler and colleagues' (2016) reviewed tablet use in schools, but could only locate 23 studies that met their inclusion criteria; therefore, they advocated for increased rigor and larger-scale studies to develop more viable conclusions. Fu and Hwang (2018) discovered that elementary students were less likely to be a participant group, and that the majority of studies focused on learning science content.

Although not as current to include newer devices like the iPad (Wu et al., 2012; Zucker, Moody, & McKenna, 2009), early investigations of mobile learning offer some insights. Limited

to 27 included studies, Zucker and colleagues examined the effects of reading digital books (e.g., eBooks, eReader books) on PK-5 students' literacy and language outcomes, and reported small to medium effects on students' comprehension, with incongruent findings related to interactive features. Wu and colleagues (2012) conducted a meta-analysis of 164 studies from 2003 through 2010, with a focus on mobile learning. Their primary finding was that the majority of the included studies focused on determining whether learning outcomes were met, with mobile phones and personal digital assistants cited as the most widely used devices. The researchers found that 86% of the studies reported positive outcomes, showing gamification techniques with the largest impact. Yet, the participants' ages ranged from elementary through graduate-level students. Additionally, Papadakis, Kalogiannakis, and Zaranis (2018) examined the truth behind self-proclaimed educational apps for Greek preschoolers. Researchers were disappointed to discover most apps emphasized skill-and-drill learning to practice letters and numbers, thus promoting rote memorization. Nonetheless, they suggested that apps could help students obtain a deeper conceptual understanding of these basic skills (Papadakis et. al., 2018).

Though earlier review studies focused on educational technology and learning have provided evidence to support technology use in the classroom, reviews investigating the use of mobile technologies within early childhood and elementary classrooms are limited. There is a need for a deeper investigation into the impact of technology on children's literacy achievement (Zhou & Yadav, 2017). However, to the best of our knowledge, no systematic review has investigated the use of mobile technologies on young children's literacy outcomes in a formal academic context. The report of the National Reading Panel (2000), *Teaching Children to Read,* determined children's reading instruction should involve the five pillars of reading: phonics, phonemic awareness, fluency, vocabulary, and comprehension. In consideration of what it means to be literate, we also include writing because reading and writing are reciprocal processes

(Tompkins, Campbell, Green, & Smith, 2017). Therefore, the theoretical framework of this systematic review study is built on the five reading pillars plus writing, heretofore referred to as literacy domains.

Research Questions and Goal of this Systematic Review

This systematic review aims to identify specific literacy gains among early childhood and elementary children using mobile technology, with the intent to inform a wider constituency and improve the integration of mobile technologies in the classroom to support children's literacy achievement. We pose the following research questions:

1. How do study characteristics (e.g., method, framework, mobile device, learning app, achievement measure, country, sample size, learner-type, usage context, age/grade-level) influence the reported outcomes of integrating mobile technologies into EC-6 literacy instruction?
2. What are the key patterns that denote the effectiveness of integrating mobile devices and applications into EC-6 literacy instruction (e.g., comprehension, vocabulary, fluency, phonics, phonemic awareness, writing), and how do patterns vary by single and multiple-case literacy domain investigations?

By investigating these questions, we expect to identify key trends between study characteristics and reported literacy outcomes, to offer direction and increased rigor in future research at the intersection of mobile technology and early literacy achievement.

Method

Search Strategy

Seven comprehensive database searches were used to find eligible studies to cover the core areas of literacy and technology. These databases included ERIC (EBSCO), Education

Source (EBSCO), PsycINFO (EBSCO), Academic Search Ultimate (EBSCO), LearnTechLib, IEEE Xplore Digital Library, and ACM Digital Library.

The search strategy was composed of synonyms and database subject terms for three primary concepts: PK-5 children, portable devices, and literacy domains. Synonyms for each concept were searched in both the title and the abstract fields, and the relevant database subject terms were searched in the subject field. Keywords searched included early childhood, preschool, young child, early learner, elementary, primary, kindergarten, mobile technology, mobile device, portable device, portable technology, ipad, tablet, laptop, literacy, reading, writing, composition, phonics, phonemic awareness, fluency, vocabulary, comprehension, listening, speaking, and visual. The database searches were limited from 2007 to August 2019, as 2007 marked the introduction of smartphones and the Amazon Kindle™ eReader. The searches were run in August 2019 and retrieved 3,183 results. After deduplication, 2,337 articles remained for eligibility screening. See Appendix A for the full search strategy. The initial search was created in ERIC (EBSCO) and modified for the other six databases.

Selection Process and Eligibility Criteria

Explicit eligibility criteria guided the screening process. For an article to be included, the study had to meet the following criteria:

- an early childhood or elementary student population (PK-5),
- use a mobile device in a classroom or school setting,
- focus on literacy outcomes,
- use a systematic approach or standardized assessment to measure achievement,
- be an empirical study,
- English language,

- publication date between 2007 and August 2019, and
- published in a peer-reviewed journal.

To reduce selection bias (Booth et al., 2016), all manuscript authors were involved in selecting the included articles. The database search results were exported to Rayyan QCRI (Ouzzani, Hammady, Fedorowicz, & Elmagarid, 2016) for title and abstract screening. To increase interrater reliability during the screening, every author screened the same 30 articles from the initial 2,337 retrieved, using the eligibility criteria. We discussed discrepancies until we reached consensus on the inclusion decision. Then, each author and a research assistant screened the remaining titles and abstracts independently. After a discussion of the discrepancies, each author and a research assistant screened the titles and abstracts independently. Following the title and abstract screening, the full text of 102 articles were assessed for eligibility by one of the authors. If an article was marked "exclude," a second author reviewed the article to confirm that the article should be excluded (e.g., technology devices were used for pretend play but were not in the study's design). Refer to Figure 1 for a flow diagram of data collection procedures.

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Data Coding and Analysis

Following the screening process and based on the inclusion criteria, 61 studies were identified as eligible for the review, which were divided amongst and comprehensively analyzed by each author. We constructed a detailed coding spreadsheet to extract study coding and facilitate information retrieval. The coding form helped to organize each study's characteristics. Since the focus of this review is to analyze the influence of mobile technology on PK-5 students' literacy achievement, we also categorized according to literacy domain. Even though we began with a broad research question to measure impact, based on the data available for analysis, we modified our research questions. Permissible to the method, "this then allows for broader

research questions to be asked at the start of the review in the knowledge that the review's scope can then be narrowed at the synthesis stage" (Gough & Thomas, 2016, p. 86).

Characteristics of the Sample

We coded for multiple characteristics within the sample to include literacy domain, research method, theoretical framework, mobile device, learning app, reported gains, achievement measure, country, sample size, learner-type, usage context, age/grade-level, journal type, and year published.

Results

Our results reveal key patterns denoting the effectiveness of mobile technologies in connection within and across the six literacy domains, grade-level, and learner type. The 61 included studies span the years 2007-2019 and include small sample sizes, ranging from one participant (McClanahan, Williams, Kennedy, & Tate, 2012) to 2,011 participants (Yamaguchi, Sukhbaatar, Takada, & Dayan-Ochir, 2014).

Literacy domain. In reference to the literacy domains central to our study's research questions, 39 studies focused on a single literacy domain, and particular literacy domains were investigated more than others (Table 1).

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The 61 studies reviewed included a total literacy domain count of 84, with 21 focused on two domains, and one that investigated three domains. There were noted patterns among the groupings when multiple domains were investigated. Most frequent pairings included phonics and phonemic awareness (n = 8), fluency and comprehension (n = 6), and vocabulary and comprehension (n = 3). Two studies included writing and comprehension, and three studies contained other combinations of the literacy domains.

Research method. Description of research method and design varied considerably. Considering all 61 included studies, research designs, when stated explicitly, ranged from Analysis of Covariance (ANCOVA) (*n* = 18; 29.51%), Analysis of Variance (ANOVA) (*n* = 13, 21.31%), *t*-tests (*n* = 4, 6.56%), descriptive statistics (*n* = 3, 4.92%), and Multivariate Analysis of Variance (MANOVA) (*n* = 2, 3.29%). In a broader sense of research design and tradition, some described their work as case study (*n* = 4, 6.56%) or mixed-method (*n* = 3, 4.92%).

Theoretical framework. Out of the 61 research studies included in this systematic review, 23 (37.70%) included one or more theoretical frameworks. Therefore, the majority of studies were not shaped by a framework (*n* = 38, 63.93%). The most widely cited theoretical framework was Mayer's (2005) Cognitive Theory of Multimedia Learning (*n* = 5, 8.20%), followed by modern learning theories, such as Cognitivism (Dror & Harnad, 2008) (*n* = 4, 6.56%). Other theoretical frameworks grounding the studies included Sociocultural Theory (Vygotsky, 1978), Technology Acceptance Model (Davis, 1986), Bandura's (1977) theory of Self-Efficacy, and Dual Coding Theory (Clark & Paivio, 1991), among several others. These more frequently cited theories were primarily used to analyze results related to the vocabulary and comprehension literacy domains. A full list of theoretical frameworks from studies reviewed is located in Appendix B.

Mobile device. In the 61 studies reviewed, 59 (96.72%) named the type of mobile device used in their literacy domain investigation. There were two (3.28%) studies that did not specify the device, and instead focused on the use of the technology app (reported in the forthcoming section). Tablets comprised the largest representation (*n* = 45, 73.77%), followed by other types of mobile devices (*n* = 11, 18.03%), which included smartphones, iPod, iRobiQ, and laptop, with eReaders the least named (*n* = 3, 4.92%). Though implemented significantly less, personal portable devices, such as the iPod, smartphone, mp3 player, and TeacherMate (*n* = 7, 11.86%),

accounted for the next most frequently used devices. The eReader was selected in three (5.08%) of the named studies, and included the Barnes & Noble™ Nook and Amazon™ Kindle eReader.

Learning app characteristics. The majority of the mobile technologies implemented in the investigations used one or more commercial apps or websites (*n* = 26, 42.62%). A small portion of the studies investigated the use of researcher-created apps and websites (*n* = 7, 11.48%) such as a tutorial game (Rogowsky, Terwilliger, Young, & Kribbs, 2018) or a word-learning app (Russo-Johnson, Troseth, Duncan, & Mesghina, 2017). There were a select number of studies that investigated the overall use of mobile technology (i.e., a device) on literacy outcomes (*n* = 6, 9.83%). There were also a large number of studies that investigated how different variations of digital books impacted literacy domains (*n* = 15, 24.59%). For instance, Richter and Courage (2017) studied how comprehension impacted students when reading a traditional book compared to a digital book. Other studies investigating eReaders looked specifically at a particular characteristic of a tablet or eReader (e.g. narration, built-in dictionary, translation features), like how the recording function on a tablet can positively impact students' reading fluency (Arens, Gove, & Abate, 2018). To comprehensively display the apps used in this study, we provide an analysis of the literacy domain focus of each app (Figure 2).

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Reported outcomes. Among the 61 studies, 36 (59.02%) reported gains, 16 (26.23%) reported mixed-results, and 9 (14.75%) identified no gains. Achievement within literacy domains demonstrates a fairly consistent pattern, where approximately half of studies indicate gains in literacy domains, meanwhile the other half reported either mixed results or no gains. Including all 61 studies, 84 literacy domains were investigated. Literacy domains with gains include: comprehension (*n* = 13, 15.48%), vocabulary (*n* =12, 14.29%), fluency (*n* = 6, 7.14%), phonics (*n* = 6, 7.14%), phonemic awareness (*n* = 5, 5.95%) and writing (*n* = 3, 3.57%). Mixed findings

within literacy domains reported the following: comprehension (*n* = 8, 9.52%), vocabulary (*n* = 7, 8.33%%), fluency (*n* = 5, 5.95%), writing (*n* = 3, 3.57%), phonemic awareness (*n* = 2, 2.38%) and phonics (*n* = 1, 1.19%). No gains in literacy domains spanned the following: comprehension (*n* = 5, 5.95%), phonics (*n* = 3, 3.57%), vocabulary (*n* = 2, 2.38%), fluency (*n* = 2, 2.38%), and phonemic awareness (*n* = 1, 1.19%). There were no studies that focused on writing as a literacy domain and reported no gains.

Studies which report mixed results are less prominent (*n* = 16, 26.23%). A broad look at the mixed results studies shows a wide variation in participant makeup, study context, app usage, as well as age and grade-level. No observable patterns were apparent when these studies were grouped together. The distribution of single domain focus and multiple domain focus was much more even when compared to studies showing gains or no gain. iPads were the most commonly identified device in mixed results (*n* = 10, 62.50%) versus the 50.82% (*n* = 31) presence of the iPad device overall. In the same way, tablet devices accounted for 81.25% (*n* = 13) of mixed results studies versus 73.77% in the overall review. As a standalone metric, this may speak to the likelihood of the iPad to produce mixed results, but that may be difficult to support as there are a myriad of other factors to consider (e.g., which apps are loaded to the device, intervention approach).

Studies reporting no gains in achievement when mobile technology is present represent the smallest percentage of the studies reviewed which in and of itself is a unique outcome for mobile technology. More broadly speaking, mobile technology is being used for the benefit of student learning and achievement across literacy domains as described above. When looking closer at the domains, studies reporting no gains illustrate a very similar pattern when the focus is single and multiple domains. Within the 9 total studies in this category, eight (88.89%) had a single domain focus while only one (11.11%) had a multiple domain focus.

Achievement measure. The majority of studies used a researcher-designed assessment to measure literacy achievement gains (*n* = 36, 59.02%), less than half of studies relied on a researcher-designed assessment (*n* = 25, 40.98%). A version of the Peabody Picture Vocabulary Test was used most frequently (*n* = 5, 8.20%), and other examples of standardized measures include DIBELS (*n* = 3, 4.92%) and Woodcock-Johnson (*n* = 2, 3.28%). Researcher-designed assessments contained comprehension questions, word knowledge tasks, sight word assessments, and non-standardized fluency probes.

Country. The majority of the included studies were conducted in the U.S. (*n* = 38, 62.30%), followed by Taiwan (*n* = 6, 9.38%), Turkey (*n* = 4, 6.56%), and Iran, the Netherlands, and Malaysia (*n* = 2, 3.28%). Each of the remaining studies were conducted in China, Malta, Australia, Canada, New Zealand, and Mongolia (*n* = 1, 1.64%).

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Sample size. Small sample sizes contain less than 100 participants, with medium sample sizes between 100-250; a large sample includes more than 250 participants (Slavin & Smith, 2009). Adhering to these guidelines, 50 (74.62%) of the included studies contained a small sample size, 7 (11.48%) were classified as medium, with 4 (6.56%) considered large). Almost three-quarters of the studies involved a sample size of 100 or less participants.

Learner-type. Learners were described in a wide variety of ways. The vast majority of included studies described learner participants in general terms by relaying the type of school (e.g., private, public) and student demographics (e.g., gender, race, socio-economic status, learner-type). On average, studies contained an equal ratio of females to males, except four studies (6.56%) where two were all male and two contained only female participants.

Out of all studies in this review, only 30 (49.18%) described specific participant characteristics. Of the studies which identified a participant characteristic, socio-economic status

(SES) was the most frequent descriptor (*n* = 7, 23.33%), followed by students with remedial reading skills (*n* = 5, 16.67%), and ELs (*n* = 5, 16.67%). Other less apparent learner-types included students diagnosed with an autism spectrum disorder (*n* = 4, 13.33%), attention-deficit hyperactivity disorder (*n* = 3, 10%), speech and language impairment (*n* = 2, 6.67%), specific learning disabilities (*n* = 2, 6.67%), dyslexia (*n* = 1, 3.33%), and gifted and talented (*n* = 1, 3.33%).

Usage context. Per the eligibility criteria for this review, all of the included studies focused on the use of mobile technologies in a classroom setting within a school. However, 37 (60.66%) studies were conducted in the inclusive classroom (mainstream instruction with the student's designated teacher), 20 (32.79%) took place within a pull-out intervention model (e.g., resource room, hallway), 3 (4.92%) did not specify the location within the school, and 1 (1.64%) study was held in an enrichment setting (e.g., gifted club).

Age/grade-level. The included studies contained a range of student ages and grade-levels. Denoted in Figure 8, 19 studies (31.15%) involved preschool students, followed by 10 (16.39%) fourth-grade, 9 (14.75%) second-grade, and 8 (13.12%) third-grade students. There were six studies (9.84%) which described their participant group as elementary-aged, but did not specify the age or grade-level.

Journal type. The included studies were most commonly published in journals with a focus on educational technology *(n* = 29, 47.54%), followed equally by general education and exceptional populations (*n* = 8, 13.11%), educational psychology (*n* = 6, 9.84%), with an equal number published in literacy and early childhood (*n* = 5, 8.20%).

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Year published. Though our systematic review search spanned 2007-2019, there were no studies in this review between 2007-2010. Instead, included studies ranged from 2011-2019,

with 34 (55.74%) published between 2011-2016, and 27 (44.26%) published between 2017-2019.

Limitations

This study contains a few limitations. First, because we targeted academic outcomes, this review only examined quantitative studies which contained a standardized or systematic approach to measure achievement. A review could be expanded to include qualitative and mixed-methodologies and those studies which also contain systematic or standardized assessment measures. Next, though we intentionally excluded conference proceedings and dissertations in an effort to increase the quality of the included research, we acknowledge that omitting these manuscript types can also increase selection bias (Booth et al., 2016). Last, though our selection criteria specifically included studies from 2007-2019, there were no included studies from 2007-2010 which met our systematic review criteria. We attribute this to the delay between research design and publication, which can take a few years.

Discussion and Critical Analysis

As a result of this systematic review of mobile literacy learning between 2007-2019, we synthesize and critically discuss the findings. As part of this review, we assembled a collection of quantitative evidence-based studies with the aim of understanding the scope of how mobile technologies contribute to the growing body of literature related to literacy outcomes for preschool and elementary students. By making connections among the findings as they relate to the literacy domains which we adapted from the National Reading Panel (2000) report *Teaching Children to Read*, we aim to a) provide mobile device and app-use strategies for teachers, while b) mapping clear research pathways for educational researchers and digital designers, with the ultimate goal of advancing the use of mobile technology to improve children's literacy achievement.

Mobile Devices and Applications Used Across the Literacy Domains

The studies identified in this systematic review described the research relative to potential literacy gains and the ways in which mobile technologies influence student learning. The findings in each of the literacy domains are presented in order of greatest frequency to help illuminate the potential and possibilities for mobile technologies. Additionally, studies that reported mixed or inconclusive findings are shared in an effort to present these missed attempts.

Comprehension. Comprehension was the most widely examined literacy domain among studies included in this analysis, and it was also most frequently paired with another literacy domain, such as phonics (Browder et al., 2017), fluency, vocabulary (Moser et al., 2017), or writing. The comprehension studies also reported the greatest variance among their findings and outcomes. Out of the studies in this review that included comprehension as a literacy domain, positive gains were most frequently noted, followed by mixed results, and negative or inconclusive findings.

While improving comprehension was the target for the studies in this systematic review, other factors such as examining features and characteristics within specific apps were not the focus in most studies. Instead, a more holistic view of students' growth was explored, mainly the investigation of students reading digital books. Studies focused on comprehension looked at how reading digital books impacted students' comprehension of text. Researchers have concluded that students who used eReaders showed a significantly higher outcome on comprehension scores than students who read printed books (Hsiao & Chen, 2015), noting a positive association among bilingual students using eReaders and their comprehension. This suggests that an alignment of technology with constructivist teaching strategies can enhance bilingual students' understanding of text (Darling-Aduana & Heinrich, 2018). More recently, researchers noted that students' problem-posing while reading interactive digital books can significantly improve students'

comprehension (Sung, Hwang & Chen, 2019). Another study with eReaders reported no statistical difference on students' comprehension; students' comprehension in the control group scores dropped while students' in the intervention group did not decline (Union et al., 2015). Although mixed results among researchers using different study designs and methods are evident, findings begin to suggest that mobile technology has the potential to support students' comprehension.

Many of the investigations that incorporated more than one app or website used comprehension as a measure for literacy gains. One study investigated the use of the Mindly and Comics Head apps with fifth-grade students, looking for gains in comprehension. Researchers found that fifth-grade students reading scores increased significantly during the study, suggesting that student-centered reading comprehension activities on the iPad can lead to increased student achievement in reading comprehension (Moon, Wold, & Francom, 2017). Mixed results related to the impact on comprehension performance is attributed to a variety of study designs, various digital book functions, as well as the apps themselves. These represent additional *text factors* that educators must account for when using mobile technology resources to support reading. For example, Redcay and Preston (2016) found that students benefited from recording and listening options, whereas Christ, Wang, Chui, and Cho (2019) relayed that hotspots negatively impacted comprehension outcomes because audio functionality lowered students' ability to infer and think critically. Much like the genres, features, and structures within the texts themselves, the structures and features of devices and apps should be carefully considered.

Another factor noted within a number of the comprehension focused studies was the idea of novelty, which created additional interest and motivation when using mobile devices (Hsiao, Chang, Lin, & Hsu, 2015; Kaman & Ertem, 2018; McClanahan et al., 2012; Moon et al., 2017; Richter & Courage, 2017). These can be seen implicitly, as researchers noted in findings and

implications that students are interested in using devices for the purpose of reading, and among some who explicitly warned their results should be interpreted with this idea in mind (Moon et al., 2017).

Vocabulary. Vocabulary was the most widely-studied literacy domain in terms of commercial app and website usage. Apps such as Sounding Board, Quicksand Rescue Mission, Proloquo2go, text messaging (Alavinia & Qoitassi, 2013), and ABC Magic were used to study different aspects of students' vocabulary understandings. In a study investigating the use of Quicksand Rescue Mission, researchers demonstrated that both middle-SES children in a lab and low-SES children in the classroom learned new vocabulary from the interactive mobile game (Dore et al., 2019). Studies using text messaging apps indicated a significant difference between mean scores for the group of students using text messaging apps with multimodal features compared to the group who did not use mobile technology (Yousefzadeh, 2012). Another finding illustrates the impact of commercial apps, such as Book Writer, on students' vocabulary knowledge. Four-year old's demonstrated growth in their expressive vocabulary, increasing an average of 1 known word at pretest to an average of 21 words at posttest; this indicates that using mobile technologies moderately impacted children's expressive verbal vocabulary (Dennis, 2016).

Many of the studies investigating vocabulary gains involved young students diagnosed with autism spectrum disorder, and focused on searching for strategies to help improve communicating more effectively with mobile devices (Agius & Vance, 2016; Coogle, Floyd & Rahn, 2018; Lorah, 2018). Researchers relayed that preschool students diagnosed with autism required more prompting when using the Sounding Board app on the iPad, yet they were able to learn a 3-step navigational sequence when using the devices (Agius & Vance, 2016). Similarly, another study which investigated vocabulary gains with preschoolers diagnosed with autism

revealed that dialogic reading delivered via both paperback and digital books increased vocabulary knowledge (Coogle et al., 2018). Lorah (2018) used Proloquo2Go on the iPad to study children's ability to discriminate between four picture-symbols and vocabulary, while providing support for the use of handheld computing devices for children with autism.

In many instances, vocabulary was paired with another literacy domain, usually comprehension. This allowed students to achieve gains in vocabulary when using apps and reading digital books. In some cases, researchers attempted to ascertain different instructional approaches because of the affordances available within the apps and mobile technology devices. For example, buddy reading was the focus of a study investigating both vocabulary and comprehension (Wang, Christ, Chiu, & Strekalova-Hughes, 2019), whereby dyad-buddies were associated with higher inference/critical thinking, and increased knowledge of vocabulary.

Fluency. Studies centered on fluency gains included a range of apps to support students' sight word fluency and word recognition (Hsu, 2013; Musti-Rao, Lo, & Plati, 2015), with an emphasis on apps with recording features to help students practice reading text passages. There were 12 studies that addressed fluency in some capacity, and six that looked at fluency and comprehension together. Two studies that targeted sight word fluency found that six and seven-year-old English Learners improved their sight word fluency as a result of using the app, Sight Words: Kids Learn (Musti-Rao et al., 2015), and that 10- and 11-year-old students with dyslexia used Facebook to increase word recognition and fluency (Hsu, 2013). Although there were only two studies which investigated sight word fluency, they emphasized accurate and rapid word naming, as well as students' ability to read passages accurately and timely.

Many of the fluency studies included students reading passages or texts of some kind. A number of them also had positive findings associated with the use of mobile technologies and students' fluent reading abilities. For instance, the use of the MCER-2 app on Asus Eeepads

facilitated elementary students' acquisition of reading skills (Lan, Sung, & Chang, 2013). Similarly, fluency gains were noted among second-grade readers when iPods were used as a tool for students to implement repeated readings and listen to the playback (Esteves & Whitten, 2011; Özbek & Girli, 2017). Moreover, the iPod and the iPad led to gains in second-graders' reading fluency, because the activity increased students' awareness and reflectiveness about their reading (Arens et al., 2018).

Six studies in this systematic review focused on both comprehension and fluency as a combined outcome (Dundar & Akcayir, 2012; Jablonski, 2019; Kaman & Ertem, 2018; McClanahan et al., 2012; Redcay & Preston, 2016; Zipke, 2017). Only one of the studies focused on how a specific app could increase students' fluency. Findings indicate that the recording and listening features of the Chatterpix app contributed to students' improvement in fluency (Redcay & Preston, 2016). The remaining studies used tablets, which enabled students to read digital books to increase their fluency and comprehension. Evidence that mobile technologies facilitated the students' fluency (and comprehension) is demonstrated through the use of the iPad, which aided fourth-graders' word recognition and moved students from frustration to an instructional level of reading over a six-week period (McClanahan et al., 2012). Additional research concluded that reading activities with digital texts helped to develop fluent reading skills among fourth-grade students, and that reading digital texts reduced the number of words read incorrectly (Kaman & Ertem, 2018). The collective analysis of findings illustrates that although mobile technologies supported different aspects of students' fluency gains, mixed and inconclusive findings still remain a concern.

Phonics/phonemic awareness. As noted in the findings, phonics and phonemic awareness were often paired together for investigation. Patterns of impact on learning when using mobile technology were often related to study design. Non-experimental studies found that

participants were meeting expectations and desired growth targets in letter and sound recognition identification and accuracy (Chai et al., 2015; Larabee, Burns, & McComas, 2014). Chai and colleagues' (2015) specifically noted that ELs in their study made much greater gains, and concluded that using mobile technology allowed them to target specific language interventions.

Quasi-experimental studies present a more mixed picture. Rogowsky and colleagues' (2018) reported significant gains among students assessed for phonological awareness and letter-sound correspondence. When investigating the differences between participant groups using digital and traditional flashcards for letter and sound acquisition, Lee (2016) found no differences. Neumann (2018) found mixed results within their study with respect to differences between students' knowledge and the learning app. To explain, participants who used apps focused on letter identification and writing and subsequently performed significantly better on post assessments for letter knowledge and identification; however, no differences were noted between experimental and control groups with letter formation. The mixed results reported in the reviewed studies indicates the importance of tailoring instructional design to meet the needs of each individual student.

The issue of app design was repeatedly discussed in the studies that focused on phonics and phonemic awareness. In a study which involved a researcher-designed phonics app, van Gorp, Segers, and Verhoeven (2016) asserted that apps to support phonics instruction should include corrective feedback, semantic meaning supports, and gaming elements. Game elements were also linked to attention and engagement to support phonics and phonemic awareness skills. Gains made in these areas were attributed to game designs and the participants' motivation to work with the apps (Huang, Clark, & Wedel, 2013; Willoughby, Evans, & Nowak, 2015). Samur (2019) discovered important distinctions that teachers should consider when selecting apps as part of their instructional design. For instance, they found that mobile apps had different impacts

depending on the structure and delivery of the content in the activity. Specifically, they noted that when content is categorized and organized, mobile apps could be effective for *learning* that content, but when content was more random or uncategorized, mobile apps were the most effective for *practicing* previously learned content.

Only ten studies in this review focused on phonemic awareness as a literacy domain. The decision to explicitly teach phonemic awareness has been a long-time debate; yet, students' need to practice with phonemes and words cannot be contested. Most of the studies examining phonemic awareness used specific apps as a strategy to support student engagement and skills practice. Five of the studies illustrated positive findings for students using mobile technologies. Researchers used different types of apps to support students' growing awareness and ability to work with the sounds and letter patterns within words. Findings indicate a positive association between kindergarteners use of phonemic awareness apps and student achievement (Bebell & Pedulla, 2015). Moreover, the use of the app Matching Game increased students' ability to distinguish between letter sounds, specifically between soft and hard c (Huang et al., 2013). Research also demonstrates that the Touch Sound app assisted early childhood exceptional learners in mastering six targeted phonemes, thereby illustrating how phonemic awareness apps can help students acquire letter sounds (Chai, Vail, & Ayres, 2015).

Writing. Few studies focused on the connection between mobile technology and writing (n = 6); this is a critical finding that should not be overlooked. Because of the inclusion and exclusion criteria that framed this systematic review, it is likely that many studies were excluded based on the requirement to include quantitative measures, which can be difficult to apply when measuring writing achievement.

The studies that were reviewed indicated positive gains for students when mobile technology was used to facilitate the writing process or specific skills used in writing. Mobile

technologies facilitated the use of more frequent and complex vocabulary, led to increased sophisticated structures in published writing products (Dunn, 2015; Liao, Lee, & Chan, 2013), efficiency and higher quality of letter formations (Patchan & Puranik, 2016), and improved standardized achievement scores on writing focused assessments (Jesson, McNaughton, & Wilson, 2015). Also present among these findings and discussions is the acknowledgement of the multimodal affordances from which students benefit when using mobile technologies. The ability to draw and visualize story ideas, which led to vocalizations and opportunities to storytell prior to the act of creating text, whether print or digital, was attributed to improvements in the overall quality of written work (Dunn, 2015; Liao et al., 2013). The tactile nature of handwriting focused apps was a significant finding for the improvement of letter formations for preschool learners (Patchan & Puranik, 2016). These studies seem to influence multiple access points from which students can initiate and develop ideas for writing. There are also implications within the reviewed studies of the evidence of a 2nd generation digital divide, indicating there are teacher-focused design issues that do not allow students of color and students from low socio-economic status homes the same types and quality of experiences when using mobile technologies for learning. While these differences were not as pronounced in the area of writing, researchers seem to posit that the use of affordances via mobile technologies is driven more by students' access and use, versus teacher design. Thus, students are taking advantage of the opportunities in spite of teacher design (Jesson et. al, 2015).

Characteristic Elements of the Included Studies

Our analysis of studies with mixed-result findings, along with elements of research design (e.g., journal-type, sample size, achievement measure) from this systematic review reveal important elements for educational researchers and digital designers to consider as they work collaboratively to improve technology integration and literacy learning in the classroom.

Research focused on mobile technology and literacy outcomes is on the rise, consistent with our finding that nearly half of included studies were published between 2017 and 2019. The overall trend observed for journal-type is that educational technology journals dominate the intersection of using mobile technology to influence literacy achievement, with nearly half of included studies from the educational technology sector. Meanwhile, only five literacy and five early childhood journals published the included studies. Also of interest among journal-types is the high occurrence of journals whose purpose is to improve learning within exceptional populations. It appears that assistive technology devices are ahead of other research that involves the use of technology for larger-scale district technology adoption initiatives; this can be explained by the high costs associated with startup device investment and professional development needed to support one-to-one technology initiatives (Topper & Lancaster, 2013).

Studies with Positive and Negative Outcomes

We classified studies by their reporting of positive, negative, and mixed findings, aligned to the study's examination of one or more literacy domains. Results suggest that mobile technology may better support instruction in some domains, but overall, mobile technology is not a strong indicator of students' literacy achievement in any one domain. In fact, tertiary factors may play a more prominent role in explaining outcomes. It is interesting to note, though limited by the number of included studies (n = 6), there were no studies that focused on writing and reported no gains.

Positively reported outcomes. In general, we noted the greatest frequency in gains among studies focused on comprehension and vocabulary. Though smaller in frequency, there were also more reported gains overall in vocabulary, phonics, and phonemic awareness. This indicates that educators might consider using mobile technology to support literacy instruction in these domains. Unique to the studies delineating gains was their focus on a single domain. Of the

36 studies which reported gains, nearly three-fourths focused on a single literacy domain. This would suggest that when an educational technology app is designed for a single purpose and intent in terms of literacy learning and performance improvement, it may be more effective as an instruction and intervention tool.

Of specific interest in studies reporting gains was many of the authors' acknowledgment of unique situational and contextual aspects that may have contributed to the gains reported in these studies. They offer warnings about broad generalizations derived from their work. Kim and colleagues' (2011) acknowledge sample size (n = 2) and participant attitudes towards technology, which were positive in their study, and concede that their findings and outcomes could be influenced by such factors. Low student-to-teacher ratios during treatments with mobile technologies were also contributing factors to the gains reported in studies (McClanahan et al., 2012; Moon et al., 2017). Teacher influence may have added to the success of mobile technology in literacy achievement. For example, Redcay and Preston (2016) observed the importance and contribution of chunking instruction. Contextual factors such as student attention and student disability were also noted. A study that contained only four non-verbal students diagnosed with Autism Spectrum Disorder found that, despite challenges with sustained attention, students improved their comprehension in the shared reading context (Spooner et al., 2014). Conversely, mobile technology positively impacted students' attention to tasks (Huang et al., 2013), with attribution to the novelty features of the apps (Moon et al., 2017).

Application design and affordances of mobile technology were contextual elements often cited among studies with gains. van Gorp, Segers, and Verhoeven (2016) noted the inclusion of corrective feedback, semantic support, and gaming elements, as vital factors contributing to the success of their participants' phonics and phonemic awareness growth. Similarly, Hsiao et al. (2015) discussed interactive features of the iRobiQ and its ability to provide meaningful

feedback in helping preschool participants' growth in comprehension. While reporting gains among their 60 participants' comprehension achievement, Hsiao and Chen (2015) could not identify factors of the eReader that contributed to improvement. This suggests that there are still design elements of mobile technology that require further investigation.

Multimodal affordances of mobile technology was cited as a contextual factor contributing to literacy achievement gains. Yousefzadeh (2012) found that students were better able to grasp and retain new vocabulary because of the accompanying visuals that were part of the text messaging apps in their study. Both visual and auditory affordances of the Learning Touch and First Sight Words Pro application led to significant gains in vocabulary growth (Xin & Affrunti, 2019). The researchers describe how the, "the Apple iPad in literacy instruction may provide an opportunity for these students to view visual images, practice correct pronunciations, and understand word meanings through visual presentations" (p. 12). Hsiao et al. (2015) echo this sentiment in their own findings, referencing the importance of the multimedia features of the intelligent and interactive robot used in their study.

No reported gains. There are important observations in regard to study design in the nine studies that reported no gains. Study design becomes relevant when studies are split according to single literacy domain cases and multiple domain cases. As shared in the results, there was one study that reported achievement in multiple literacy domains. This may suggest that a multiple domain focus is not a predictive factor towards positive achievement outcomes. Additionally, eight of the nine studies with no reported gains used tablet devices.

In a single case design with no gains in literacy, Boeglin-Quintana and Donovan (2013) explored the impact on kindergarten students' fluency after listening to stories on the iPod during independent reading for six-weeks. Though the study included a treatment and control group, and student engagement and reading time increased, it is possible the findings were limited by

the six-week timeframe. In another example, three preschool students diagnosed with Autism spectrum disorder used the iPad to improve their vocabulary through a picture exchange system, yet the program required excessive prompting and had never been implemented with preschool-aged children (Agius & Vance, 2016).

In the remaining studies, researchers were unable to identify a statistically significant difference between treatment and control groups with the use of print and digital text types. No differences were detected when students were asked to blend phonemes with flashcards on the iPad (Lee, 2016), improve Spanish comprehension with the Duolingo language learning app (Rachels & Rockinson-Szapkiw, 2018), boost preschoolers' comprehension during the shared reading experience (Richter & Courage, 2017), and increase third-graders' reading comprehension when reading print and digital books (Wright, Fugett, & Caputa, 2013). Though a moderate sample size of just over 100 students, only 16 received the treatment of reading with a tablet (Wright et al., 2013). This study also required students to complete assignments on the tablet at-home, a difficult variable to account for given the range of at-home support available to students. Researcher-design decisions also appear to influence literacy achievement. For example, student learning was measured with only one teacher-created 11 question comprehension assessment (Dundar & Akcayir, 2012). With regard to the importance of selecting a specific type of digital book, preschoolers were drawn to hotspots, which could explain why children paid closer attention to the letters in the print book (Willoughby, Evans, & Nowak, 2015). Despite detecting no differences in achievement, findings from these studies indicate that the digital substitution for paper is equivalent to using paper-based methods. Of final interest are three studies make an interesting qualification regarding their findings, stating that even though there were no gains to report in their measured literacy domain, there were also no losses (Boeglin-Quintana & Donovan, 2013; Rachels & Rockinson-Szapkiw, 2018; Wright et

al., 2013). Boeglin-Quintana and Donovan (2013) balance their finding of no gains by asserting that participants in their study demonstrated elevated levels of motivation and self-efficacy when using mobile technology.

Mixed Results Studies

Mixed results in single domain studies. Of the 16 mixed results studies, 7 are studies which investigated a single literacy domain; these studies varied widely and results appear to be influenced by design. Mixed results manifested in treatment types and participant groups. For example, Smeets and Bus (2012) found that when presented with digital learning opportunities that were varied in type of question and experience, students performed differently and were able to demonstrate vocabulary knowledge in unique ways. For instance, students demonstrated vocabulary knowledge more effectively by responding to multiple choice questions compared to interactions with digital hotspots embedded in interactive storybooks. Because of their distraction and incongruence, hotspots were ineffective. Meanwhile, use of apps which required students to use their finger to trace capital letters and receive haptic device feedback led to achievement gains, in comparison to traditional letter writing practice. In their study investigating the inclusion of iPads on students' phonemic awareness and phonics understandings, Neumann (2018) found that participants' letter knowledge increased significantly after using various iPad apps, but their letter writing skills showed no significant gains. This study suggests a difference in mobile technologies' impact on, and improvement of students' knowledge within some literacy domains, as they relate to the use of a particular app.

Using a similar focus, Russo-Johnson and colleagues' (2017) found that particular population groups performed differently depending on the type of tactile interaction. For instance, boys in a passive treatment (i.e., watching only) condition performed better than boys in the dragging or tapping treatment. On the other hand, girls and students in low socio-economic

status groups demonstrated the greatest gains when dragging and manipulating within the mobile app versus tapping or passive viewing. In another example, researchers working with a single emergent bilingual student saw the student's vocabulary performance grow dramatically after implementing a digital book app as an intervention strategy. Rivera, Mason, Moser and Ahlgrim-Delzell (2014) explain,

> at the beginning of the year, [Tammy] would give me a book to read to him and have him point out certain words but he didn't really make that connection. He would just listen to me read versus the iPad where he was able to blow up (i.e., magnify) the pictures and stories and point to the letters and highlight. I think it was more fun. It made it fun versus just the book and flipping papers (p. 42).

In another related study, Larabee and colleagues' (2014) make a similar suggestion regarding participant groups. Even with a small sample size, the emergent bilingual students in the study made significantly greater gains in letter sound knowledge than native English speakers. These mixed findings indicate that certain tasks and apps may be better suited than others when targeting individual learning needs, and that these factors should be accounted for when making intervention decisions.

Mixed results in multiple domain studies. The remaining mixed results studies represent those that investigated multiple literacy domains (n = 9), most of which have findings related to the mobile technology better serving one domain over the other (Smeets & Bus, 2012; Kaman & Ertem, 2018; Rodriguez & Cumming, 2017; Zhou & Yadav, 2017; Zipke, 2017). A common pattern that emerged in these multiple domain studies is that the use of mobile technology to support comprehension often results in no effect or a non-significant effect. O'Toole and Kannass (2018) investigated the impact of the narration features of digital book apps, and identified significant improvements in vocabulary, but no significant impact or

difference in comprehension. A similar conclusion was made in regard to the connection between levels of questioning and multimedia affordances of mobile apps. Vocabulary performance was identified as a significant gain, but no comprehension impact could be noted (Zhou & Yadav, 2017).

Comprehension and fluency often illustrated a similar pattern. Zipke (2017) found that word recognition and fluency were significantly better when using digital book apps, but no gains in comprehension were noted. Though not a significant difference, the digital book treatment group performed better than the traditional print book group. In a mobile technology app intervention with a medium-sized sample, Kaman and Ertem (2018) found that fluency performance increased, but the performance in comprehension was less consistent. The intervention produced positive gains initially, but comprehension results diminished as the intervention persisted. This raises the issue of novelty with the use of mobile technology in literacy interventions. Will the effectiveness persist once the novelty of the technology is no longer present?

Future Research

As identified within this review study, research where mobile technologies have served as a mechanism to improve children's literacy has been increasing steadily over the past few years. An examination of each study's characteristics and outcomes allows us to suggest an abundance of future research opportunities. Our intention of providing these recommendations is twofold: a) to improve the use of educational technology for instruction in the literacy domains, while selecting standardized achievement measures to more accurately gauge the effectiveness of mobile technology use, and b) to design and report literacy and technology studies more effectively, while providing more clarity and transparency when reporting study characteristics.

Digital Design and App Development

Based on the inconsistency among app choices and the inability to replicate researcher-designed apps, we recommend that digital designers and app developers create a comprehensive technology app or multiple apps intended to target age- or grade-level instruction in the six literacy domains. With this in mind, our semantic feature analysis (refer to Figure 2) provides guidance in instructional and research design decisions.

With the introduction of these new apps, researchers should, in partner with school administration and classroom teachers, design replicable larger-scale studies (e.g., medium sample size or larger) which use an experimental design and standardized achievement measure to measure the effectiveness of the new, commercially-designed technology apps. This would also allow for an investigation into how mobile devices pre-loaded with these literacy domain apps could be leveraged to support student learning outside of the school setting.

Rigor in Research Design

To improve rigor in research and develop a more nuanced understanding of teaching literacy with mobile technology, we recommend researchers make a more concerted effort to ground their research within a theoretical framework. Ultimately, the goal is to carefully develop theories to help conceptualize the process of teachers integrating technology and their students use of multimedia to develop their literacy skills. Additionally, we draw attention to the opportunity for researchers to conduct a review of qualitative or mixed-method studies that are considered "sound," to include studies that are highly descriptive in nature for data gathering, analysis, and reporting procedures (Pimmer, Mateescu, & Gröhbiel, p. 492). Three-fourths of the included studies contained a small sample of less than 100 participants, with 18 (29.51%) of the studies containing a sample size of less than 20 participants. With small sample sizes, it is difficult to gauge the reliability of quantitative analyses. With a larger sample size, for example, studies which include an ANOVA or ANCOVA analysis may be more replicable and reliable

than a study that can only measure outcomes with descriptive statistics. With increased rigor, (e.g., quasi-experimental), we recommend researchers report the effect size so others can further interpret the research design and findings. Building on the idea of conducting more rigorous research studies, a systematic review of using mobile devices to support literacy domain instruction for students in grades 6-12 could also contribute insights to improve literacy and technology integration in secondary education, while informing technology integration within the earlier grades (e.g., secondary education technology apps could be adapted for elementary literacy instruction). We hope that the evidence presented in this review study will compel digital designers, researchers, and school administrators to critically question their technology integration strategies, while working collectively to measure the effectiveness of the invested technologies.

Conclusion

The purpose of this systematic review study was to examine the impact of mobile technologies on PK-5 children's literacy achievement and illuminate opportunities to improve research and practice where mobile technologies support children's literacy. This systematic review speaks to the necessity for transparency in the reporting of participant characteristics, for the applicability of the study to other contexts, as well as the need to employ and appropriately describe standardized achievement measures to address reliability and replicability. This study is pivotal for teachers in practice, teacher educators, and researchers, because it demonstrates the importance of using mobile apps to ensure alignment between the app characteristics and the learning goals (e.g., literacy domain). Furthermore, multiple interventions and/or apps may need to be implemented to improve students' literacy over time. Collectively, this systematic review of 61 included studies serves to reinforce the vital nature of design processes, both research and

instructional, and provides sharpened insights into integrating mobile technologies within literacy instruction.

Statement on Conflicts of Interest

We declare that we have no conflicts of interest.

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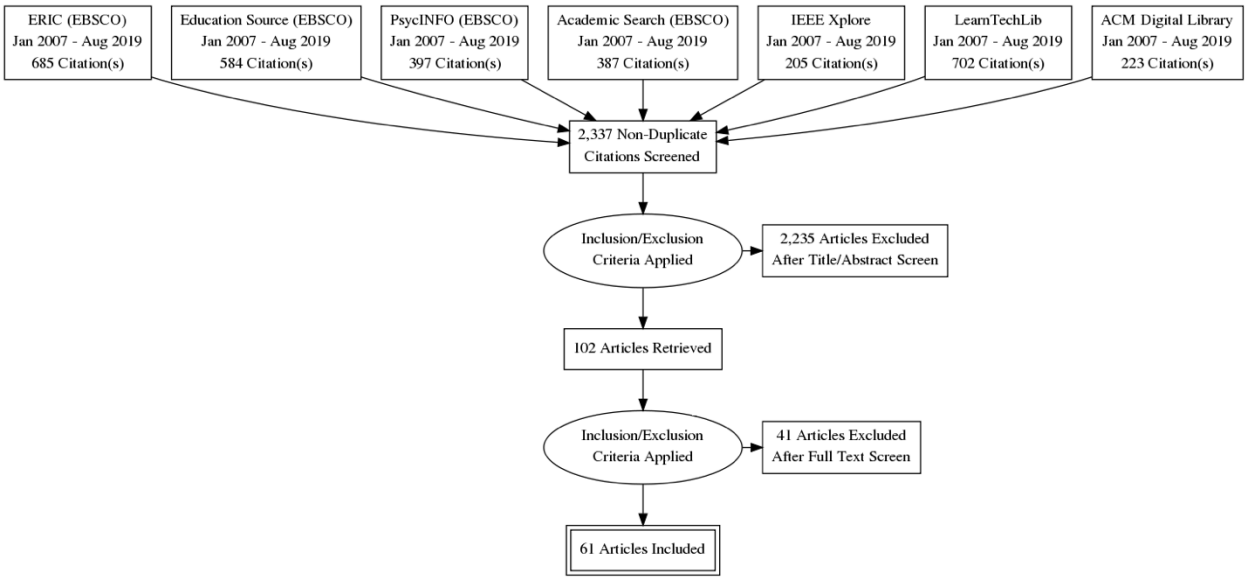

Figure 1. Flow diagram of data collection

	Researcher-Designed	Free	App	Literacy Domain Investigated					
				Phonics	Phonemic Awareness	Fluency	Vocabulary	Comprehension	Writing
ABC Magic	--	+	+	--	+	--	--	--	--
Alphabet Tracing	--	+	+	--	+	--	--	--	--
Book Writer	--	+	+	--	--	--	+	--	--
Chatterpix	--	+	+	--	--	+	--	+	--
Doodle Buddy	--	+	+	--	--	--	--	--	+
Duolingo	--	+	--	--	--	--	+	--	+
Educreations	--	+	+	--	--	--	--	+	--
E-flashcards	+	O	+	--	--	--	+	--	--
Endless Alphabet	--	--	+	+	+	--	--	--	--
Facebook	--	+	X	+	+	--	+	--	--
First Sight Words Pro	--	--	+	--	--	--	+	--	--
GoTalk Now	--	--	+	--	--	--	--	+	--
Kes Sesi	+	+	--	+	--	--	--	--	--
Language Builder	--	X	+	--	--	--	+	--	+
MCER 2	+	O	+	--	--	+	--	--	--
My Pet Typing	--	+	--	--	--	--	--	--	+
New-word Learning App	+	+	+	--	--	--	+	--	--
Polar Bear Horizon	--	--	+	--	--	--	+	--	+
Proloquo2Go	--	--	+	--	--	--	+	--	--
Quicksand Rescue Mission	+	+	+	--	--	--	+	--	--
Reading Race	--	+	+	+	+	--	--	--	--
Sight Words: Kid Learn	--	+	+	--	--	+	--	--	--
Sounding Board	--	+	+	--	--	--	+	--	--
Text Messaging	--	+	+	--	--	--	+	--	--
Touch Sound	+	+	--	--	+	--	--	--	--
WK-ebook	+	O	--	--	--	--	+	+	--
Writing Wizard	--	--	+	+	--	--	--	--	+

-- NO + YES 0 UNSURE X BOTH

Figure 2. Apps and their characteristics

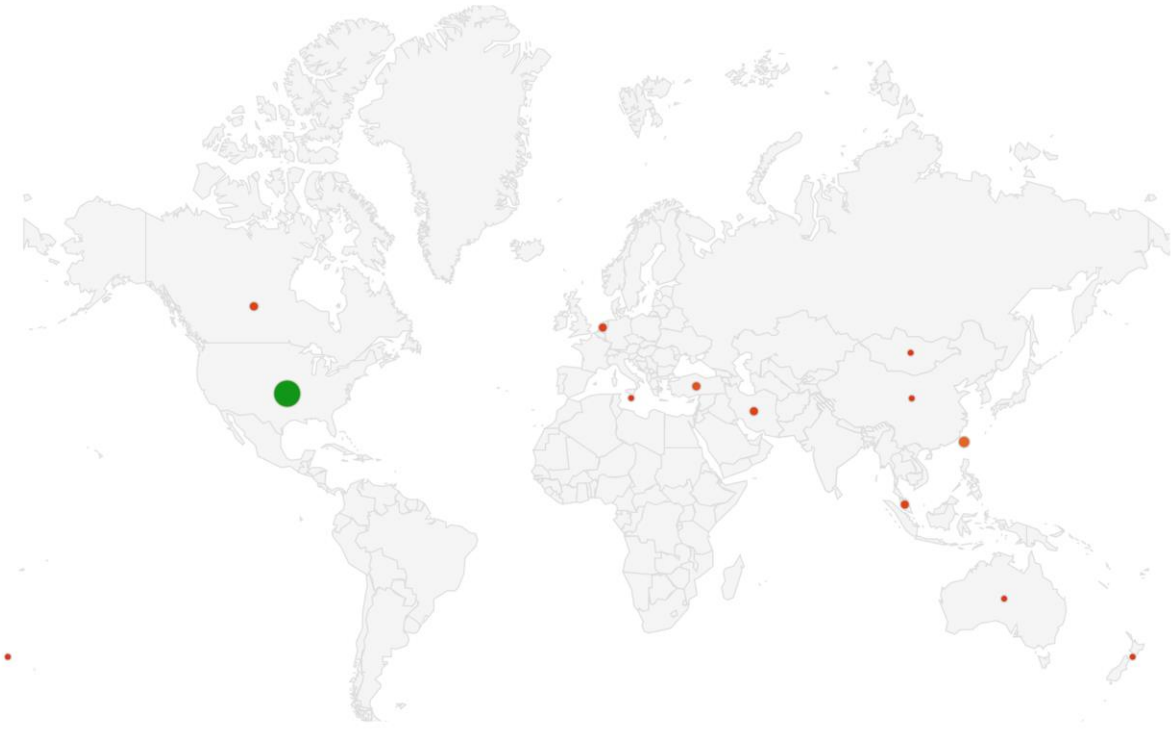

Figure 3. Country dispersion of included studies

Table 1. Literacy domain investigations (*n* = 84)

Single Domain Studies (*n* = 39)	
Vocabulary	16
Comprehension	12
Fluency	5
Writing	3
Phonemic Awareness	2
Phonics	1
Multiple Domain Studies (*n* = 22)*	
Phonics, Phonemic Awareness	8
Fluency, Comprehension	6
Vocabulary, Comprehension	3
Writing, Comprehension	2
Phonics, Comprehension	1

Vocabulary, Writing	1
Fluency, Vocabulary, Comprehension	1

*22 studies that include 2-3 literacy domain foci = 45 domains

Table 2. Journal-type codebook (n = 61)

Journal Category	Example Journals	*n*
Educational Technology	*Computers & Education; Tech Trends*	29
Education (General)	*AERA Open; The Curriculum Journal*	8
Exceptional Populations	*Journal of Special Education Technology; Research and Practice for Persons with Severe Disabilities; Augmentative and Alternative Communication*	8
Psychology	*Reading Psychology; Frontiers in Psychology*	6
Literacy	*Reading Research Quarterly; Reading and Writing*	5
Early Childhood	*Early Childhood Research Quarterly; Journal of Early Intervention; International Journal of Play*	5

Appendix A

ERIC (EBSCO) Search Strategy

Search limited to January 2007 to 2019

((DE "Preschool Education" OR DE "Early Childhood Education" OR DE "Primary Education" OR DE "Elementary Education" OR DE "Preschool Children" OR DE "Young Children" OR DE "Toddlers" OR DE "Elementary School Students" OR DE "Kindergarten" OR DE "Grade 1" OR DE "Grade 2" OR DE "Grade 3" OR DE "Grade 4" OR DE "Grade 5") OR TI ((“early childhood” OR preschool* OR “young child*” OR “early learn*” OR two-year-old* OR three-year-old* OR four-year-old* OR pre-kindergarten OR pre-K OR elementary OR primary OR kindergarten* OR “first grade*” OR “second grade*” OR “third grade*” OR “fourth grade*” OR “fifth grade*” OR “grade* 1” OR “grade* 2” OR “grade* 3” OR “grade* 4” OR “grade* 5” OR “grade* one” OR “grade* two” OR “grade* three” OR “grade* four” OR “grade* five”)) OR AB ((“early childhood” OR preschool* OR “young child*” OR “early learn*” OR two-year-old* OR three-year-old* OR four-year-old* OR pre-kindergarten OR pre-K OR elementary OR primary OR kindergarten* OR “first grade*” OR “second grade*” OR “third grade*” OR “fourth grade*” OR “fifth grade*” OR “grade* 1” OR “grade* 2” OR “grade* 3” OR “grade* 4” OR “grade* 5” OR “grade* one” OR “grade* two” OR “grade* three” OR “grade* four” OR “grade* five”))

AND

((DE "Handheld Devices" OR DE "Laptop Computers") OR TI (mobile N2 tech* OR mobile N1 device* OR portable N1 device OR portable N1 tech* OR handheld N1 device* OR mobile n1 phone* OR app OR apps OR ipad* OR ipod* OR kindle* OR “Microsoft Surface” OR laptop* OR tablet* OR smartphone* OR iphone* OR android OR leappad OR leapfrog OR

leaptop OR samsung) OR AB (mobile N2 tech* OR mobile N1 device* OR portable N1 device OR portable N1 tech* OR handheld N1 device* OR mobile n1 phone* OR app OR apps OR ipad* OR ipod* OR kindle* OR “Microsoft Surface” OR laptop* OR tablet* OR smartphone* OR iphone* OR android OR leappad OR leapfrog OR leaptop OR samsung))

AND

((DE "Literacy" OR DE "Reading" OR DE "Reading Ability" OR DE "Reading Comprehension" OR DE "Writing (Composition)" OR DE "Writing Ability" OR DE "Phonics" OR DE "Phonemic Awareness" OR DE "Vocabulary" OR DE "Vocabulary Skills" OR DE "Listening Skills" OR DE "Listening" OR DE "Listening Comprehension" OR DE "Speech Skills" OR DE "Speech Communication" OR DE "Visual Perception") OR TI (literacy OR read* OR writ* OR composition OR phonic* OR “phonemic awareness” OR fluency OR vocabulary OR comprehen* OR listen* OR speak* OR visual) OR AB (literacy OR read* OR writ* OR composition OR phonic* OR “phonemic awareness” OR fluency OR vocabulary OR comprehen* OR listen* OR speak* OR visual))

Appendix B

Theoretical Frameworks in Accordance with Literacy Domains

Theoretical Framework	Reviewed Studies	Examined Literacy Domain(s)
Technology Acceptance Model (Davis, 1986)	Hsiao & Chen, 2015; Hsu & Hwang, 2013	comprehension
Theory of Multimedia Learning (Mayer, 2005)	Li & Tong, 2019; Richter & Courage, 2017; Smeets & Bus, 2012; Rivera, Mason, Moser, & Ahlgrim-Delzell, 2014; Wang, Christ, Chiu & Strekalova-Hughes, 2019	vocabulary comprehension
Modern Learning Theories (e.g., Cognitivism, Dror & Harnad, 2008)	Connor, Day, Zargar, Wood, Taylor, Jones & Hwang, 2019; Kim, Hagashi, Carillo, Gonzales, Makany, Lee, & Gàrate, 2011; Redcay & Preston, 2016	vocabulary comprehension fluency
Sociocultural Theory (Vygotsky, 1978)	O'Toole & Kannass, 2018; Rachels & Rockinson-Szapkiw, 2018; Wang, Christ, Chiu & Strekalova-Hughes, 2019	vocabulary comprehension
Socio-constructivist (Crook, 2002)	Kim, Hagashi, Carillo, Gonzales, Makany, Lee, & Gàrate, 2011; Lan, Sung & Chang, 2013	vocabulary fluency
Linguistic processing (e.g., Sénéchal & Cornell, 1993)	Connor, Day, Zargar, Wood, Taylor, Jones & Hwang, 2019	vocabulary
Transactional theory (Rosenblatt, 1982)	Christ, Wang, Chui, & Cho, 2019	comprehension
New literacies theories (Kress, 2003)	Christ, Wang, Chui, & Cho, 2019	comprehension
New literacies theory for the internet and ICTs	McClanahan, Williams, Kennedy, & Tate, 2012	comprehension fluency

(Leu, Kinzer, Coiro, & Cammack, 2004)		
Dual coding theory (Clark & Paivio, 1991)	Yousefzadeh, 2012; Zhou & Yadav, 2017	vocabulary comprehension
Self-efficacy (Bandura, 1977)	Rachels & Rockinson-Szapkiw, 2018	vocabulary
Supportive interactivity (Zucker, Moody, & McKenna, 2009)	Russo-Johnson, Troseth, Duncan, & Mesghina, 2017	vocabulary
Belajar Membaca Tanpa Mengeja, play approach (Noviana, 2013)	Puspitasari & Subiyanto, 2017	vocabulary
STORY Mnemonic strategy (Dunn, 2014)	Dunn, 2015	writing
Model-lead test strategy (Wolery, Ault, Doyle, & Gast, 1986)	Rivera, Mason, Moser, & Ahlgrim-Delzell, 2014	vocabulary
Funds of knowledge (Moll, Amanti, Neff, & Gonzalez, 1992)	Rivera, Mason, Moser, & Ahlgrim-Delzell, 2014	vocabulary
Playful pedagogy (Moyles, 2010)	Rogowsky, Terwilliger, Young, & Kribbs	vocabulary phonics