Young children and tablets: A systematic review of effects on learning and development

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Young children and tablets: A systematic review of effects on learning and development

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Abstract

Mobile applications are popular among young children, yet there is a dearth of studies examining their impact on learning and development. A systematic review identified 19 studies reporting learning effects on children 2 to 5 years old. The number of children participating in experimental, quasi-experimental, or mixed-method studies was 862 and in descriptive or correlation studies, 941. The majority of studies reported positive effects on literacy development, mathematics, science, problem-solving, and self-efficacy. Among the factors explaining observed effects were design features, the role of adults, and a similarity between applications and transfer context. Although drawing firm conclusions remains a challenge, this review forms a first step towards systematic research in the field and contributes to shaping directions for future research.

KEYWORDS

early years, learning, mobile devices, tablets, young children

1 | INTRODUCTION

Mobile devices such as tablets, iPads, and smartphones have been increasingly used by young children including toddlers and preschoolers (Holloway, Green, & Livingstone, 2013). The tactile-based digital interface of touch screens enables digital interactions earlier in the development of preschoolers or even toddlers and infants (Plowman, Stevenson, Stephen, & McPake, 2012) and a greater degree of independence when interacting with this technology compared to computers (Holloway et al., 2013). The last few years the design and release of mobile applications targeting early years' learning presents the greatest growth in online application stores with 72% of the educational applications targeting preschool- or elementary-aged children (Shuler, Levine, & Ree, 2012). In the United States, amongst the 2–4 years old, 39% are found to have used a smart device (iPad or iPod; MDG Advertising, 2012). In the UK, 40% of the 3–4 years olds make use of tablets at home (OfCom, 2014). In Sweden, 50% of children aged 3 and 4 are found to use tablets and 25% smartphones (Findahl, 2013).

As such, touch screen mobile devices and applications warrant special consideration. They present distinct affordances including their lightweight design, portability, relatively intuitive interface use, communication features, and affordable cost (e.g., Vavoula & Karagiannidis, 2005). They hold the potential to revolutionize learning through flexible, personalized, and mobile educational experiences. They can scaffold synchronous and asynchronous types of learning, customized instruction and individualized assessment, rich communication, and learning anywhere and anytime (Mehdipour & Zerehkafi, 2013). Despite their increasing uptake and the potential for new and interactive forms of learning, there is limited understanding of their impact on young children's learning and development.

Although an extensive body of research has been dedicated to the investigation of the cognitive, socio-emotional, and health impact of older media, including TV, video games, the Internet, and cell phones, on children and adolescents (Calvert & Wilson, 2011; Strasburger, Wilson, & Jordan, 2009), few studies have been explicitly focused on examining the impact of touch screens, including tablets, iPads, and smartphones, on young children (Crescenzi, Jewitt, & Price, 2014; Lieberman, Bates, & So, 2009; NAEYC, 2012; M. M. Neumann & Neumann, 2014; Starcic & Bagon, 2014). Existing research has been mainly focused on late primary years, elementary school, and higher education (Haßler, Major, & Hennessy, 2016; Miller, Robertson, Hudson, & Shimi, 2012; Nolan & McBride, 2014; Plowman et al., 2012; Wu et al., 2012).

The aim of this paper is, through a systematic review of resources in technology, education and psychology-based databases, to identify and critically analyse the impact of touch screen devices on young children's learning and development and the factors explaining possible effects. This review can benefit diverse stakeholders, including parents, educators, psychologists, policymakers, researchers, and mobile application designers, by providing insights as to whether mobile applications have a positive, negative, or neutral effect on young children's learning and the conditions (e.g., design features, social interaction, and developmental age) under which they can be of most benefit to young children. It is hoped that recommendations from this review will spark new and systematic research in the field leading to a robust understanding of young children's interactions with mobile technology and the design of pedagogically sound mobile learning applications.

1.1 | Rationale

A systematic review of the impact of touch screen devices and mobile applications on young children's learning and development is timely for a number of reasons. First, it can shed light on long-standing controversy in the field. Curriculum policy recommendations stress the importance of information, technology, and society (ICT) experiences in early years to set the foundations for ICT efficiency in later years (Siraj-Blatchford & Siraj-Blatchford, 2000). On the other hand, a large body of research raises concerns about the use of mobile devices by young children. The American Academy of Pediatrics (2016) discourages any time interacting with media screen other than video chatting for children younger than 18 months old and advices for joint parent–child interactions. Memory constraints related to age place limitations on what children can learn from 2D media including touch screens. In particular, toddlers present an inability to transfer learning and information from 2D media to 3D contexts resulting in a transfer deficit. This transfer deficit could be reduced by providing additional relevant visual and auditory cues that will help children retrieve information from memory (Barr, 2013). What is meant by “screen time” is yet to be determined. Screen time might be a positive experience for children when related to activities such as reading and watching educational television whereas negatively perceived when, for example, watching videos in a passive manner.

Second, this review can inform educators, policymakers, parents, and designers in certain ways. Early years curricula provide no specific recommendations about which mobile applications best support learning, more likely due to the lack of empirical evidence and the relatively new release and diffusion of those technologies (M. M. Neumann & Neumann, 2014). Schools make choices and uses of technology based on individual needs. In addition, there is an absence of high-quality educational applications that could be used in early years' learning. The current state of the art is the use of rote-learning applications (Herold, 2015). As Hirsh-pasek, Zosh, Michnick, Gray, and Robb (2015, p. 26) describe “we live in the first wave of app[lication] development, when applications are often just migrations of games and learning scenarios that already exist in non digital form.” The absence of evidence-based guidelines in respect of which applications should be labelled as “educational” raises obstacles to the choices made by parents and teachers and places under scrutiny claims made by application developers in terms of their educational value (Shuler et al., 2012).

As a consequence, the choice of educational applications in formal and informal settings is informed by evidence about other types of technologies, such as the passive television viewing literature, and the “hype” presented in popular media by, for example, application developers, more likely leading to erroneous decisions. In other cases, educational applications are evaluated by qualified educators as a means of guidance to educators and parents (e.g., www.educationalappstore.com) or by rating systems such as the Common Sense Media (www.commonsensemedia.org/). Although the teaching expertise of educators might be an appropriate way to highlight applications that are suitable for young children's learning and development, the evaluation of mobile applications is not yet based on evidence from experimental research that considers for the actual interaction of children with specific applications and their comparison to baseline measurements. For example, the design of an application might be educationally sound as evaluated by experts, yet an examination of actual use may reveal that children's previous knowledge or memory deficits create misconceptions and lead to poor learning.

Third, this systematic review aims to critically engage with existing research, identify potential strengths and weaknesses and how these may affect the interpretation and generalization of research outputs, and recommend fruitful areas of future research that are either underexplored or not yet effectively explored. It is anticipated that it will work as a stepping stone for shaping future directions of research and providing evidence-based recommendations to a range of stakeholders in this area.

1.2 | Aim and research objectives

This systematic review aims to collect evidence about whether and, if so, what learning gains emerge from young children's interaction with tablets, iPads, and smartphones in both formal (e.g., school) and informal (e.g., home) settings. The specific research objectives (ROs) to be addressed are

> RO1: What evidence exists (positive, negative, or neutral) about the impact of tablets (or iPads or smartphones) on young children's (5 years old and younger) learning and development (social, emotional, or cognitive)?

Experimental studies with randomization of participants and comparisons between control and treatment groups are expected to effectively address this objective and provide robust evidence of impact on young children's learning and development. Randomization can control for pre-existing differences amongst participants whereas the formation of a control group ensures that no confounding variables bias the comparisons. Quasi-experimental studies do not meet the randomization principle, yet they were considered in this analysis, and their findings were critically assessed given the noncomparability of groups under study and the lack of control groups.

> RO2: What conditions explain the impact of tablets (as identified in RO1) on children's learning and development?

Experimental studies that control for specific variables are expected to provide insights to this question, for example, how applications' interactivity compares to video watching and which condition better support learning. In-depth descriptive methods of data collection (e.g., interviews, questionnaires, and observations) are expected to also provide insights about the conditions that evidence any impact of tablets on learning including the factors that better support or hinder learning processes.

1.3 | Literature search process

An extensive automated search of electronic resources in nine databases took place in February 2017. These databases were Web of Science, Google scholar, Science Direct, ACM Digital library, Wiley online library, Ebsco ebooks, ERIC, psycINFO, and the institutional library search engine. Technology, education, and psychology-based resources were used. Three different sets of keywords were utilized to extract relevant resources: (a) tablets (or iPads or touch screens or mobile devices or mobile applications), (b) learning (or development), and (c) young children (or preschool or preschooler). A chronological restriction was also applied for resources published between 2009 and 2017. A Boolean logic search (e.g., learning or development) or individual keyword combination search were used as allowed.

1.4 | Inclusion and exclusion criteria

A set of criteria was set to ensure that only literature relevant to answering the research objectives of this study was included in the analysis. Inclusion criteria were as follows:

(a). resources reporting on the use of tablets (Android-based or iPads and smartphones);
(b). examining learning impact (social, emotional, or cognitive);
(c). reporting on young children 5 years old or younger. Studies with multiple age groups were included, and reference was only made to findings about the age group under examination;
(d). describing empirical research either experimental or descriptive in formal and/or informal settings;
(e). resources were published after 2009 to correspond with the launch of Android devices in 2009 and Apple iPads in 2010; and
(f). English was the written language used.

Studies excluded from the analysis were reporting, for example, on the engaging qualities of tablets (e.g., Walter-laager, Brandenberg, Tinguely, Pfiffner, & Moschner, 2016), usage patterns (e.g., Amornchewin & Sitdhisanguan, 2016), tablets as tools for data collection (e.g., Ryokai, Farzin, Kaltman, & Niemeyer, 2013), perspectives without empirical data (e.g., Sheehan & Uttal, 2016), and used iPods, digital books (e-books), or touch screen apparatus (e.g., Zimmermann, Moser, Lee, Gerhardstein, & Barr, 2016). Grey literature, that is, nonpeered review resources, was not included in the analysis.

1.5 | Assessing the quality of included resources

Nineteen studies were selected as meeting the inclusion criteria. This decision was made after reading the abstract or skimming the full text of resources (in cases where the abstract information was not adequate for addressing the inclusion and exclusion criteria) and ensuring that all inclusion criteria were met. Data sets were accessed in the order presented above. An Excel sheet with studies meeting the inclusion criteria was created. Any new study identified was compared to the existing list of studies and added to it, if not already included. If the search engine results were large in number, a maximum of 250 entries from each database was examined. Less relevant or irrelevant studies were identified after the first 120 entries. Skimming 250 entries was therefore a safe threshold for not excluding any relevant study from the analysis.

To assess further the quality of each resource, selected studies were categorized in terms of whether they were journal, conference, or book items and whether they adopted an experimental, descriptive, or a mixed-methods methodology. Also, content mapping was performed to visualize information related to authors, year of publication, number of research participants, instruments used for data collection, research variables, results, general conclusion, and mapping to research objectives (see Table S1).

2 | RESULTS

Nineteen studies (*N* = 19) met the inclusion criteria of reporting learning effects of touch screen devices (tablets, iPads, and smartphones) on young children (5 years old and younger) and published after 2009. The majority of studies were published in 2016 (*N* = 12) indicating a recent interest from the research community to understand and document the impact of mobile devices on young children. The age of participating children ranged between 2 and 5 years old. The total number of children participating in experimental, quasi-experimental, or mixed-method studies (*N* = 14) was 862 and in descriptive and correlation studies, 941 (*N* = 5). The minimum number of children taking part in research was 24 (experimental study) and the maximum 715 (survey study). Eight studies (*N* = 8) reported findings on literacy development, eight (*N* = 8) on science, technology, engineering, and math (STEM) mainly mathematics, of which one study reported also socio/emotional effects, and three studies (*N* = 3) on generic skills such as problem-solving, collaboration, and fine motor skills' development. Only two studies examined the use of mobile devices in formal education. In the next paragraphs, evidence from these studies is critically analysed.

2.1 | Literacy development

Five experimental and quasi-experimental and four descriptive studies examined effects of touch screens on young children's literacy development, in particular reading and writing, vocabulary acquisition, knowledge of digital print, and emergent literacy skills. The use of e-books or digital books by young children did not form part of this analysis, yet studies reporting on the use of tablets or iPads for reading books were included in the review. Two quasi-experimental studies presented contradicting evidence as to whether touch screens are (not) superior than traditional books. Touch screens were found to lead to better performance than nondigital books (Masataka, 2014) yet to inferior outcomes in parent–child reading activities (Krcmar & Cingel, 2014). This contradiction should be interpreted in light of a lack of control over the testing and use of books by children and their mothers at home in the former study and the addition of extra features to touch screens (narration and highlight function) to the selected books in the latter study. The effects of touch screens on reading skills were more strongly determined by Reich, Yaw, and Warschauer (2016) in their review of studies comparing e-books and traditional books. The authors concluded that well-designed e-books can help children learn equally good and in some cases better than print books. Yet, enhanced e-books with animations, sounds, and games were found to distract children. Learning with the support of adults is more beneficial in print books as conversations focus on the content of the book as opposed to e-books and a focus on the affordances of the medium.

Only one experimental study examined emergent writing skills (writing of uppercase letters) and reported no differences in post-tests between paper and pencil and tablet and stylus conditions. Yet, the use of tablet with finger (tactile condition) was found to be superior than the use of tablet with a stylus. Despite the similarity between writing with a pencil and with a stylus, no evidence of near transfer was reported. The same study examined extrinsic and intrinsic feedback. Extrinsic feedback in the tablet condition was found to have no additional benefit over intrinsic (visual when writing; Patchan & Puranik, 2016). The immediate feedback provided by the device when an error is made was not found to have an advantage over the visual feedback occurring when writing with a pencil.

In terms of vocabulary acquisition, two experimental studies reported positive effects of touch screens on vocabulary acquisition and development, yet the greatest benefits were observed when use was accompanied by adults (Teepe, Molenaar, & Verhoeven, 2016; Walter-laager et al., 2016). The four descriptive studies identified reported positive outcomes from children's interaction with touch screens as reported by parents and teachers, in particular observed improvements in knowledge of digital print (Beschorner & Hutchison, 2013), letter sound and name writing skills, print awareness, print knowledge, and sound knowledge (M. Neumann, 2014; M. M. Neumann, 2016), and initial key concepts in literacy in particular for girls (Clarke & Abbott, 2016). No relation of time using the tablet with emergent literacy skills was found (M. Neumann, 2014).

2.2 | STEM development

Eight studies (five experimental) examined effects of touch screen devices on STEM development, in particular, mathematics and science. These studies examined whether mobile applications facilitate near and far transfer of learning. Near transfer is achieved when learning is transferred from one occasion to another with similar deeper structure and with or without different surface characteristics. On the contrary, far transfer occurs when learning is applied to instances identified as far away from initial learning such as the application of the law of supply and demand to explain high prices when visiting a supermarket (Schwartz, Chase, & Bransford, 2012). Improvements after interacting with mobile devices were reported for near (yet not far) transfer learning events relevant to telling the time and measuring with unconventional units, quantity of different sets, growth, and projectile motion for older children only, early number skills for low-income children, Math enhancement using digital manipulatives, content knowledge about pets, and an increasing complexity of ways of reasoning about Math. Studies made use of both educational applications and commercial mobile games, including Nintendogs and Angry Birds.

The use of mobile applications was found to effectively support near but not far transfer incidents. Two experimental studies evidenced transfer of learning about time (Wang, Xie, Wang, Hao, & An, 2016) and measurement of animals (Alade, Lauricella, Beaudoin-ryan, & Wartella, 2016). In both studies, the inherent interactivity (e.g., manipulating items on the screen) of mobile applications was found to support near transfer learning. To explain this further, for example, in Alade et al. (2016), study children in the intervention groups either played an interactive measurement game or watched a non-interactive video version of it. The control group played a non-STEM game about cleaning animals. Following the intervention, a number of knowledge transfer tasks were completed by children with the help of a researcher in a quiet place. These tasks were composed of a set of printed images that asked children to measure the height and length of objects using items such as legos and erasers. In the near task, children were presented with information similar to the game or video used in the intervention; they were asked to measure animals with the help of a scaffold line that demonstrated the correct direction of measurement. In contrast, in the far task, similarity between the game or video and the task was limited; children were asked to measure a robot (rather than animals), and the scaffold line was absent. Findings revealed that children in the interactive (game condition) scored better in the near task than the control and non-interactive groups. What was surprising and in contrast to the body of literature suggesting that interactivity or experiential learning (Kolb, 2014) and physical engagement (Kontra, Lyons, Fischer, & Beilock, 2015) facilitate learning is that children in the non-interactive condition performed better in far transfer task than the control and the interactive condition. Interactivity was found to support specific forms of learning, that is, near transfer learning, yet not others (i.e., far transfer learning). This finding aligns well with experimental evidence from Schroeder and Kirkorian (2016) showcasing that older children only (aged 4–5 years old) achieved far transfer from watching a video rather than interacting with an application about the quantity of different sets and growth. Younger children (aged 3 and 5 years old) were found to learn better from a video than a mobile application, yet no transfer was achieved. No effects of character familiarity on learning were identified (Schroeder & Kirkorian, 2016).

These findings come in contrast with a large body of literature showcasing benefits for learning through exploration and interaction with physical items (e.g., Kolb, 2014; Kontra et al., 2015). Yet, they could be explained by children's limited working memory and increased cognitive load. Manipulating items on the screen (interactive condition) required a significant amount of working memory resources and, as a result, may have limited children's ability to complete the far transfer task (which was cognitively more demanding than the near transfer one). This was not the case for the near transfer task, as similarity between the interactive condition and the transfer task more likely helped children mimic the manipulation actions they used in the game and successfully applied them to the task in hand (Alade et al., 2016; Schroeder & Kirkorian, 2016).

The developmental abilities of children including their age were found to relate to the impact of touch screens on young children. In line with Schroeder and Kirkorian's (2016) study, in a pre- and post-evaluation of the game Angry Bird, Herodotou (2016) reported significant differences in both game performance and knowledge about projectile motion between 4 and 5 years old. Learning improvements were recorded only for the group of 5 years old, in particular, an understanding of how force affects projectile motion and the prediction of the pathway of a ball as a parabola, but not for the 4 years old (Herodotou, 2016). Transfer of learning from a commercial game-based context to a near transfer pen and paper (i.e., children were presented with images that showed a sling shot, as presented in the game, and were asked to draw the motion of a ball before it lands to the ground) exercise was only partially achieved for older children. The impact of commercial games on learning was also examined in a quasi-experimental case study by Miller et al. (2012) making use of the game Nintendogs. Pre- and post-tests revealed improvements in knowledge about pets after playing the game Nintendogs and enhanced self-worth and self-efficacy. Participating teachers reported also enhanced peer interaction.

One experimental study was considered for the role of children's socio-economic status and the potential of mobile devices to bridge previous gaps in learning and development. Low-income children were randomly allocated to a control and treatment groups. Improvements in early number skills (e.g., quantity discrimination and numeral identification) after interacting with a Math application were observed for the treatment group. These differences equal to learning of approximate 1 year more Math than children in the control group (Schacter & Jo, 2016).

Lastly, the role of digital manipulatives hosted on mobile devices was examined in an experimental and a quasi-experimental study. The former study reported mutual benefits from using both digital and traditional manipulatives for improving Math concepts (Mattoon, Bates, Shifflet, Latham, & Ennis, 2015). The latter study reported on more complex ways of reasoning about Math concepts, the more children use a variety of digital manipulatives. Design features supporting learning were the open-ended nature of tasks, variety of representations, and levels of difficulty (Watts et al., 2016).

2.3 | Generic skills development

One experimental and two descriptive (one large-scale survey and interviews with educators) studies made reference to more generic skills in relation to tablet use. In particular, B. Huber et al. (2016) reported on improvements in problem-solving, planning ability, and executive functioning in both a transfer and a nontransfer randomly allocated groups when solving a digital and a physical puzzle game (the tower of Hanoi), advocating in favour of mobile applications to learn problem-solving skills. In a large-scale survey with 715 parents, Bedford et al. (2016) reported no negative associations between age of first touch screen usage and developmental milestones as well as no relation between touch screen use and either gross motor or language milestones. Yet, earlier scrolling of the screen was associated with earlier fine motor achievement. Finally, in a qualitative study in formal settings, Clarke and Abbott (2016) reported multiple perceived benefits from using tablets (one device per child) in classrooms, in particular for girls, including early development of peer assessment through collaboration, growth in confidence, and better listening skills and group work.

3 | DISCUSSION

The lack of research examining the impact of touch screen devices including tablets, iPads, and smartphones on young children has been stated extensively. This systematic literature review revealed an increasing interest in conducting examinations towards this direction as evidenced in the number of studies published in 2016 (N = 12) and the comparatively lower number between 2012 and 2015. Nineteen studies met the inclusion criteria and were integrated in this review. All studies were published in academic journals in the fields of psychology and education. The great majority of studies (N = 14) made use of an experimental (N = 9) or quasi-experimental research design (N = 5). Such research designs, in particular, experimental studies, are appropriate for concluding on the impact of mobile devices on young children and enhance our confidence in the robustness of the reported findings and their generalizability across the population of young children.

This systematic review aimed to address two research questions. The first question (RQ1) was what evidence exists about the impact of tablets (or iPads or smartphones) on young children's (5 years old and younger) learning and development (social, emotional, or cognitive)? Fourteen studies reported positive effects from using tablets devices; four studies reported mixed findings (both positive and negative; Alade et al., 2016;Herodotou, 2016 ; Patchan & Puranik, 2016 ; Schroeder & Kirkorian, 2016); and one study reported negative only findings (Krcmar & Cingel, 2014). A dearth of studies examining the effects of mobile devices on children younger than 2 years old was observed. Participating children were in the range of 2 to 5 years old. The great majority of studies examined cognitive effects on science and mathematics (N = 16), with only three studies examining generic skills such as problem solving and fine motor skills' development. The social and emotional effects (or no effects) of mobile devices on young children are considerably underexplored, with the exception of two classroom-based examinations making reference to enhanced peer interaction (as observed by teachers) and emotional effects including enhanced efficacy and self-worth from completing game tasks (as measured through pre- and post-tests; Beschorner & Hutchison, 2013; Miller et al., 2012).

The 14 studies reporting positive effects from using tablets devices concerned enhanced vocabulary skills (Teepe et al., 2016; Walter-laager et al., 2016), reading and writing skills (Beschorner & Hutchison, 2013; Masataka, 2014; M. Neumann, 2014; M. M. Neumann, 2016), enhanced Math or science knowledge and skills (Alade et al., 2016; Mattoon et al., 2015; Miller et al., 2012; Schacter & Jo, 2016; Wang et al., 2016; Watts et al., 2016), earlier fine motor development (correlational study; Bedford et al., 2016), enhanced problem-solving skills (S. Huber, Krist, & Wilkening, 2003), and general improvements in literacy, numeracy, social interaction, and growth in confidence (case study; Clarke & Abbott, 2016). Mixed findings were reported in relation to emergent writing skills and science knowledge and skills of older children (Herodotou, 2016; Patchan & Puranik, 2016; Schroeder & Kirkorian, 2016). The one study reporting on negative findings referred to reading ability in joint parent–child interactions (Krcmar & Cingel, 2014).

The second research question (RQ2) aimed to detail the conditions that explain the impact of tablets on children's learning and development. The 19 studies under examination investigated the following conditions: (a) Application features including interactivity supporting near transfer (Alade et al., 2016; S. Huber et al., 2003; Wang et al., 2016) yet being an obstacle to far transfer (where video was found to be more effective; Alade et al., 2016), narration and highlight functions supporting reading performance (Masataka, 2014), open-ended tasks, variety of representations and levels of difficulty supporting refinement of Math ideas (Watts et al., 2016), extrinsic feedback not supporting writing on a mobile device over naturally occurring feedback when writing on paper (Patchan & Puranik, 2016), and no effects of character familiarity on learning (Schroeder & Kirkorian, 2016); (b) the role of adults leading to greater vocabulary growth (Walter-laager et al., 2016) yet negative outcomes in reading due to evaluative comments about the medium (Krcmar & Cingel, 2014); (c) age of children including greater benefits for older children in near transfer tasks (Herodotou, 2016; Schroeder & Kirkorian, 2016; Wang et al., 2016); (d) similarity between mobile applications and transfer context (near transfer) was found to facilitate learning, yet writing with a stylus was not found to support learning despite similarity when writing with a pen (Patchan & Puranik, 2016). Far transfer was achieved when children watched instead of playing with applications (Schroeder & Kirkorian, 2016); and (e) one-device-per child was observed to lead to cognitive benefits in diverse domains especially for struggling students and girls (Clarke & Abbott, 2016).

It could be argued that the line of research examining the conditions under which mobile applications are more beneficial to young children is still in its infancy. Despite the promising initial insights, more examinations need to be done to identify how app design and social conditions surrounding use such as clear goals, feedback, interaction with others and children's individual characteristics such as age, gender, and previous attainment support or inhibit both surface and deep forms of learning. In terms of app design, one of the few studies available (Falloon, 2013) examined a range of apps and their features and how may affect the learning pathways of 5 years old. The effectiveness of apps was judged based on whether children could complete the app tasks in hand and was engaged. Features found to influence learning pathways were embedded scaffolds (e.g., modelling and reflection time), corrective and formative feedback, text-to-speech functionality, and impediments (e.g., advertisements and buying content). Despite the usefulness of these outcomes for designing engaging and easy to complete mobile apps, more research is needed to identify how design features may inhibit or facilitate learning as measured by performance indicators over and above app's task completion such as pre- or post-tests and comparisons between apps that share similar learning goals.

Towards this direction and drawing from the science of learning, Hirsh-pasek et al. (2015) proposed a set of conditions that is deemed to be essential for achieving deep learning. Children learn best when an application enables them to be actively involved and engaged with the learning materials, is meaningful and relates to their lives, and interacts with others in a high-quality manner; materials have clear learning goal and support scaffolded exploration around a specific learning goal.

4 | CONCLUSIONS

This systematic review forms a starting point for building an in-depth understanding of the impact of mobile devices and applications on young children's learning and development. The extensive search of academic databases revealed a limited number of empirical studies (N = 19) examining learning effects of tablets, iPads, or smartphones on children 5 years old and younger; therefore, drawing firm conclusions remains a challenge. Yet, two facts are quite promising; the research community is increasingly interested in conducting research in the field and adopts experimental methodologies with randomization to study effects on learning, an approach that can yield robust and conclusive evidence.

The great majority of the 19 studies included in this review examined cognitive effects of mobile devices on young children, relevant to mainly literacy, science and Math, and reporting positive outcomes. There is a lack of studies examining possible impact of mobile devices on children's social and emotional development and a need for gaining a fine-grated understanding as to why observed effects have been identified. Experimental methods and random allocation of participants into groups minimize allocation bias and controls for differences between participants (Sullivan, 2011). Yet, they do not consider for the factors explaining observed differences unless these are built in the design of the study. A mixed-methods approach with, for example, follow-up interviews or debriefing of use, could enrich and explain experimental findings and provide insights as to the conditions under which the use of mobile applications might be more beneficial for young children.

As Lieberman et al. (2009) suggest, research approaches should shift from “proof-of-concept” examinations demonstrating, for example, the potential of technology for learning and types of learning gains (skills and knowledge), towards studies that are longitudinal in nature to identify long-term effects of use and overcome novelty effects that might occur in short-scale implementations, recruit large samples to allow for multivariate analysis and group comparisons, and theory-driven investigations that draw from established theories of children's development. Future studies should build on the outcomes from this review and design investigations that consider for established theories of learning, the affordances of mobile devices and specific mobile applications, and are structured upon collaborations between educators, psychologists, academics, and researchers to design high-quality applications for learning.

In addition, evidence from experimental studies such as Schacter and Jo (2016) that considered for the socio-economic status of children and identified benefits for children from low-income backgrounds after interacting with Math applications is very promising for closing attainment gaps and should pave the way for additional research in the same direction. Further studies should seek to establish whether and under what conditions mobile devices could be used to minimize previous attainment gaps amongst children from diverse socio-economic backgrounds and help children reach their maximum potential.

In the same line of thinking, what is still lacking is to determine how mobile interventions compare to existing approaches to teaching and learning in early years along with detailing the pedagogical conditions that can better support mobile learning in formal and informal settings. In terms of the former, there is a lack of studies comparing mobile learning with existing teaching approaches and identifying whether this form of learning is more or less beneficial. For example, literacy effects could be examined by comparing mobile literacy apps with focus group multisensory techniques involving elements such as creating and acting out stories, which are found to be beneficial for oral language development and spoken skills (Fricke, Bowyer, Haley, Hulme, & Snowling, 2013). Another example relates to understanding science concepts and vocabulary and how science-related apps compare to approaches such as responsive (i.e., child-initiated learning supported by materials and opportunities provided by the teacher such as playing in parallel with children and describing what children are doing and saying) and explicit teaching (i.e., explicit introduction of concepts and vocabulary words), a combination of which was found to be effective compared to responsive only teaching (Hong & Diamond, 2012).

In terms of the latter, it remains unknown what an effective technology-enhanced early year curriculum looks like. Research needs to move over and above mere descriptions of mobile uses in the classroom or teaching perceptions to evaluating specific integrations of mobile devices into the teaching practice. Mobile devices and apps could be used in diverse ways in the classroom. An example is how the game Nintendogs was used by four teachers as a "contextual hub" for a project studying pets. The game was used as a kick-off stimulus or a learning resource during the lesson. Teaching was child-centred with tasks such as group activities, inquiry learning, and connections to children's lives outside school. The degree of teacher's direction versus student autonomy varied across teachers whereas a problem-solving approach with prompts or a team working setting was used interchangeable by different teachers (Miller et al., 2012). Such varied approaches need to be systematically compared to identify the exact pedagogical conditions that better serve students when using mobile devices and lead to optimal learning outcomes. Well-planned integration of apps in the classroom, with clear learning objectives and appropriate feedback could motivate children, enhance concentration, and support independent learning and communication (Flewitt, Messer, & Kucirkova, 2014).

Towards this end, it might be useful to draw from a well-established body of research examining the effects of other media on children to guide future research. Studies on the cognitive effects of television viewing (e.g., Barr, 2011) suggest that attention, patterns of looking time, and imitative behaviour are fruitful areas for investigation as they can give information about children's comprehension of the content, what characteristics of the stimuli (e.g., sound, comprehensibility, and repeated presentations) might facilitate understanding and what role mediation of viewing by adults might have on attention and learning. Television studies have also been focused on examining the prosocial effects of media (e.g., Strasburger et al., 2009). The interactive and social features of touch screen media suggest new forms of prosocial behaviour that merit examination including understanding what characteristics of the media or of certain applications might affect emotional competences, how children might relate to application characters and exhibit empathy or accepting or rejecting others. Moreover, given the play-like character of mobile applications in early years, it might be fruitful to examine how interaction with such technologies relates to children's imaginary play, their understanding of the distinction between fantasy and reality and the extent to which interaction with this new media enriches their imaginative and creative capacities (see Singer & Singer, 2011).

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