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An Integrative Study of the Effect of Early Learning with Touchscreen Technologies Using SAMR Framework: A Meta-analysis and Systematic Review

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Abstract

Digital technologies have brought about a remarkable shift in early childhood learning. Among different technological devices, touchscreens have attracted special interest among young children given their intuitiveness and interactive features. However, the existing empirical findings regarding the effect of this technology on young children's learning are not consistent. Touchscreen technologies have been also postulated to have the potential for transforming learning experiences. However, there is a dearth of research explicating if the transformative potentials of touchscreens are benefited in early learning and examining the factors/conditions contributing to the improvement of young children's learning with touchscreens. To address these gaps in the literature, the present research was performed using an integrated format, consisting of an already published systematic review on the effect of touchscreens on early learning and a meta-analysis/systematic review. This research targeted four relevant objectives: 1) to provide comprehensive up-to-date evidence of the pooled effect of touchscreen technology on early childhood learning, 2) to investigate the effect of factors/conditions acting as potential moderators on young children's learning with touchscreens, 3) to provide an up-to-date systematic review of how touchscreens are integrated into early childhood education based on the SAMR framework, and 4) to explore if the touchscreen integration levels (i.e., transformative and enhancement levels of SAMR) vary the effect of learning with these devices. The meta-analysis estimated the overall effect of touchscreen devices on the learning performance of 2- to 8-year-old children and examined the moderators of this effect, based on a total of 59 effect sizes derived from 57 empirical articles. The overall analysis was indicative of a significant touchscreen learning effect (d=0.48), demonstrating the beneficial effect of learning with touchscreens for young children. Furthermore, the moderator analysis revealed that learning domain, adult's feedback, and technology integration level significantly moderated the impact of touchscreens on early learning outcomes. Research implications give different stakeholders, such as instructional designers, educators, and teachers, insights into the impact of touchscreens on early learning under different conditions to benefit from these educational tools for improving early learning.

Keywords: Early learning, Early literacy, Touchscreens, SAMR model, Technology integration

Summary for Lay Audience

Digital technologies have remarkably shifted childhood environments and learning experiences. Among different technological devices, touchscreens have attracted special interest among young children because of their intuitiveness and interactive features. The present research consists of an already published systematic review (on the effect of touchscreens on early learning) and a meta-analysis/systematic review. This research targeted four relevant objectives: 1) to provide comprehensive up-to-date evidence of the pooled effect of touchscreen technology on early childhood learning, 2) to investigate the effect of factors/conditions acting as potential moderators on young children's learning with touchscreens, 3) to provide an up-to-date systematic review of how touchscreens are integrated into early childhood education based on the SAMR framework, and 4) to explore if the touchscreen integration levels (i.e., transformative and enhancement levels of SAMR) vary the effect of learning with these devices. The meta-analysis estimated the overall effect of touchscreen devices on the learning performance of 2- to 8-year-old children and examined the moderators of this effect, based on 59 effect sizes derived from 57 empirical articles. The overall analysis demonstrated the beneficial effect of learning with touchscreens for young children (*d*=0.48). Furthermore, the moderator analysis revealed that learning domain, adult’s feedback, and technology integration level significantly affected children’s learning with touchscreens. This research can give teachers/educators and policy makers insights into the impact of touchscreens on early childhood learning under different conditions.

Co-Authorship Statement

This integrated-article thesis consists of two research papers. Chapter three of this thesis has been published in the Education and Information Technologies journal, co-authored with my supervisor, Dr. Mi Song Kim. Furthermore, part of chapter three (systematic review paper) has been presented at the AERA Annual Meeting 2022. Chapters four to six will be submitted to the Computers & Education journal, co-authored with Dr. Mi Song Kim and Dr. Takumi Uchihara, assistant professor of Applied Linguistics at Waseda University. The meta-analysis study has been also submitted to the AERA Annual Meeting 2023. Dr. Mi Song Kim, the MA candidate's supervisor, designed the study and provided guidance and critical feedback for our data collection and analysis. I, as a student researcher, took the lead in data collection, analysis, and manuscript drafting. Dr. Takumi Uchihara consulted us with the data analysis part of the meta-analysis. Dr. Mi Song Kim and Dr. Takumi Uchihara fully support the inclusion of our manuscript as chapters for Atefeh Taherian Kalati's MA thesis.

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Chapter 1

1. Introduction

1.1 Background & Context

Technologies have gained an undeniable role in twenty-first century education. Different technological tools and resources have induced great modifications in the way one learns and teaches (Yellend, 2006). The consideration of these shifts in education is a matter of significant importance, especially in early childhood learning, since the twenty-first century children are experiencing a fast-changing era of digital technologies and are growing up as digital natives. As stated by Bruns (2005), the emerging generations are 'no longer producers or consumers, publishers or audiences, but both at the same time' (p. 15). Regarding this, we can no longer suffice with the traditional models of education involving the transmission of knowledge in a lecture format with the students sitting in straight rows as the receivers of knowledge (Harrell & Bynum, 2018). This highlights the need for the reconsideration of the educational settings and approaches by integrating technologies into early educational settings to keep this young net generation engaged and improve their learning outcomes and experiences.

The need for consistent educational reform has been also clearly pointed out by John Dewey (1944), a prominent educational reformer and philosopher, asserting, "If we teach today as we taught yesterday, we rob our children of tomorrow" (p. 167). Consequently, if we are to prepare children for their future life and equip them with twenty-first century skills (i.e., critical thinking, communication, collaboration, and creativity), we should consider the pragmatic utilization of technologies in early childhood classrooms.

1.2. Touchscreen Technology in Early Childhood Education

Among various emerging technologies used by the current young generation of learners, touchscreens have gained wide popularity in early childhood settings given their extensive affordances and features (Holloway et al., 2013; Lovato & Waxman, 2016). The tactile interface of touchscreens enables young children to interactively engage with the contents/concepts on the screen through such simple actions as touching, swiping, and pinching (Lovato & Waxman, 2016), without any spatiotemporal constraints.

The increasing uptake of touchscreen technology in childhood educational environments has resulted in the implementation of a great number of studies examining the affordances and impacts of these devices on childhood learning. These studies have reported a mixed set of findings regarding the effects of touchscreens on childhood education. The variability of research findings undermines the robustness of the learning effects of these devices (Xie et al., 2018) and makes the early childhood educators/teachers insecure or uncertain about integrating technologies into their pedagogical settings. Accordingly, there is a need to perform a study to provide a comprehensive overview by exploring the combined effect size of learning with touchscreens on early learning performance.

The variability in research findings is also indicative of the presence of potential moderating factors that can affect the outcome of learning with these devices. However, the majority of the research in early learning has been primarily concerned with the impact of touchscreen technology on learning, while failing to focus on the factors/conditions facilitating or debilitating learning with these technologies (Xie et al., 2018). To fill these gaps in the literature, in this research, I adopted a meta-analysis approach to provide up-to-date comprehensive evidence on the consistency of touchscreens' impact across a wider range of populations and interventions. This research design would also facilitate the exploration of the moderating effect of the factors/conditions potentially accounting for the success or failure of touchscreen-enhanced pedagogical attempts in early learning environments.

The research on the effect of technology on learning is usually focused on one of the two aims of either addressing the direct impact of technology-based instructions on student's learning outcomes, specifically their academic achievement in different subject areas (i.e., primary outcomes), such as literacy and mathematics, or targeting the influence of technologies on the pedagogical setting and learners' learning experience, like learners' engagement, motivation, or collaboration (i.e., secondary outcomes) (Doris et al., 2021). However, the present study investigates the impact of touchscreen technologies on both primary and secondary outcomes because they are complementary and of equal importance in improving students' learning performance.

1.3 Technology Integration and SAMR Framework

An important point that should be considered in educational technology is that "no technology has an impact on learning in its own right; rather, its impact depends on how it is used" (Clark & Luckin, 2013, p. 4). Accordingly, the availability and use of technology alone cannot enhance learners' achievement; rather, how a piece of technology is selected and integrated into the educational environments determines the outcome (Livingstone, 2012).

Regarding this, we need to focus on 'how' questions in addition to the 'what' questions since the sole presence of technology affordances does not guarantee their fulfillment unless we know how to leverage their learning benefits.

The incorporation of new technologies into the classroom settings requires the modification of current pedagogical approaches (Geer et al., 2017). The consolidation of technologies with learner-centered instructional approaches can allow for the creation of new learning opportunities that encourage authentic and active learning (Goodwin, 2012; Shuler et al., 2012). The significance of technologies lies in their potential to transfer children's learning experiences by allowing the teachers to do activities, which were not feasible in the absence of technologies (Murray & Olcese, 2011). Despite the growing use of touchscreens in early childhood pedagogy, the extent to which these devices have been used to enhance or transform young children's learning is not well understood yet (Crompton & Burke, 2020; Diemer et al., 2013).

Different frameworks have been developed so far to investigate the effective integration of technologies into educational settings. These frameworks include the Technological, Pedagogical, and Content Knowledge framework (TPACK; Koehler & Mishra, 2009), the Replacement, Amplification and Transformation (RAT, Hughes et al., 2006), the Technology Integration Matrix (Florida Center for Instructional Technology, 2013), and the framework of Substitution, Augmentation, Modification and Redefinition (SAMR; Puentedura, 2009).

Among these frameworks, the SAMR model was used in the present study because of its higher responsiveness to the research objectives (i.e., describing and categorizing the uses of technology for educational purposes). The SAMR framework has been proposed to be responsive to the evaluation of technology integration into educational settings (Arnold, 2019), especially mobile learning, which partly involves touchscreens (Fabian & Maclean, 2014; Pfaffe, 2017; Romrell et al., 2014; Woodruff & Wagner, 2019). Moreover, as acknowledged by Bernacki et al. (2020), this framework provides the educators with a different lens that facilitates the recognition of the benefits of learning with mobile technology, compared to learning with more traditional approaches. The SAMR model conforms to the constructivist approach as it considers learners’ interaction with the technology-based activities and how their learning process/outcome is affected by the integrated technology (Tunjera, & Chigona, 2020). It is argued that the adoption of this model for technology integration allows the learners to construct their own learning based on their experiences during the learning process (Binangbang, 2020).

Drawing on the RAT and TPACK frameworks, the SAMR model allows for the categorization of the incorporated technology at four tiers, namely substitution, augmentation, modification, and redefinition, offered in order of their sophistication and transformative power (Puentedura, 2006, 2009, 2013). As displayed in Figure 1, technology is integrated at the first two levels of substitution and augmentation to enhance learning, while it is implemented at the two levels of modification and redefinition towards transforming learning. The substitution level is ascribed to a situation where technology only acts as a direct substitute and is utilized for a task that could be accomplished without the use of technology. On the other hand, redefinition refers to the learning conditions in which technology is employed for the creation of new opportunities that were previously inconceivable without technology (Puentedura, 2006).

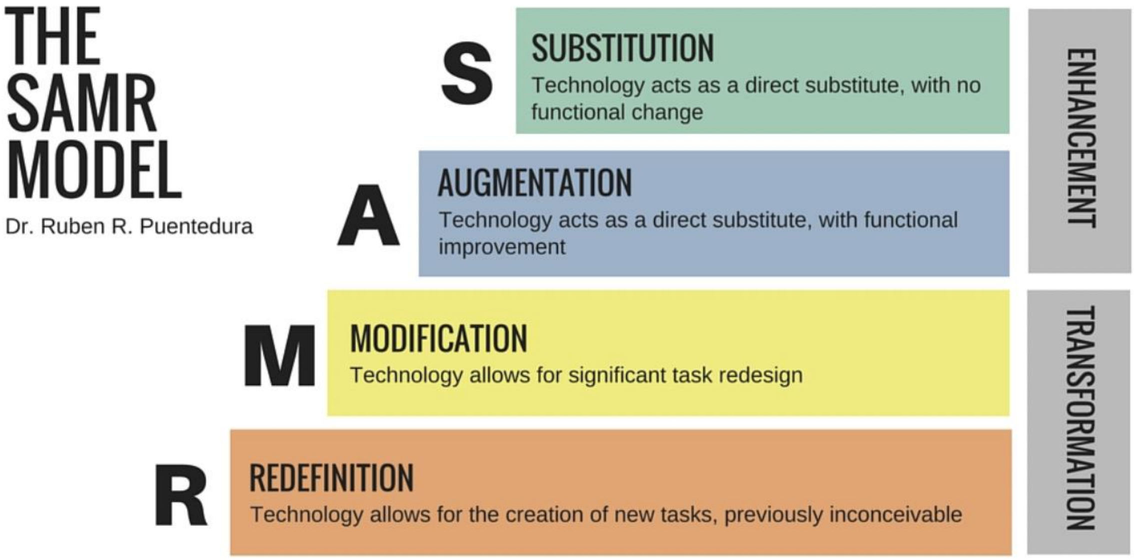

Figure 1: Substitution, Augmentation, Modification, and Redefinition (SAMR) model

Note. Adapted from "The SAMR Model and the Technology Integration Matrix" by R. Winkelman, 2020, *Teaching and Learning with Technology, Technology Integration Models*.

According to the literature, the type of learning activities is a key factor in a technology-based pedagogical attempt (Dorris et al., 2021). Being recognized as an ideal framework for categorizing the type of technology-based activities, the SAMR model can be used as a helpful tool for achieving a better understanding of how a technology-based educational intervention might work better. However, despite the relevance and popularity of SAMR for the examination of technology use/integration in educational settings, there is a handful of studies using this framework for PK-12 levels, with no study specifically using this model for examining technology integration into early childhood environments.

Thus, the present study aims to fill the gap in the literature by covering both the 'what' and 'how' questions of early learning with touchscreens and using the SAMR framework to provide an overview of the trend of using touchscreens in early childhood learning research. Drawing on the SAMR framework, this study explores if touchscreens, in the context of early childhood education research, are used to transform learning or to enhance the existing learning activities as measured by different levels of this model. The included studies were explored to examine how the touchscreen-based learning experience fell within the substitution, augmentation, modification, and redefinition spectrum.

Moreover, the touchscreen integration level based on the SAMR model was used as the potential moderator of the effect of touchscreens on early learning. The exploration of SAMR levels as a potential moderator in the present meta-analysis can demonstrate the moderating effect of using touchscreens at each of the transformative and enhancement levels on young children’s learning performance and provide us with an insight into the technology integration level that leads to more favorable outcomes in the context of early childhood education. While the results of the meta-analysis can address the ‘what’ question by providing objective evidence of the effect of touchscreens on early childhood learning, the integrated systematic review and the moderator analysis (as part of the meta-analysis) can cover the ‘how’ question by identifying the factors/conditions affecting young children’s learning with touchscreens and examining them statistically.

1.4 Research Objectives

This integrated thesis targets four relevant objectives: 1) to provide comprehensive up-to-date evidence of the pooled effect of touchscreen technology on early childhood learning, 2) to investigate the effect of factors/conditions acting as potential moderators on young children's learning with touchscreens, 3) to provide an up-to-date systematic review of how touchscreens are integrated into early childhood education based on the SAMR framework, and 4) to explore if the touchscreen integration levels (i.e., transformative and enhancement levels of SAMR) vary the effect of learning with these devices.

1.5 Research Questions

Considering the research objectives, the questions that are addressed in this study are:

1. What is the overall effect of touchscreen technology use on early childhood learning?

2. Do any moderators affect early learning with touchscreens?

3. Within early childhood learning studies, what levels of the SAMR framework are the young learners engaged in when using touchscreens for educational purposes? Is there a trend regarding the levels of SAMR in specific subject areas?

4. Does the outcome of learning with touchscreens vary across different levels of touchscreen integration (i.e., SAMR levels) in different subject areas?

1.6 Significance of the Study

This study carries several implications for different stakeholders, such as instructional designers, educators, and teachers, by giving them insights into the impact of touchscreens on early childhood learning under different conditions. The findings of this study can contribute to the policymakers and practitioners to make evidence-informed decisions in relation to the integration/use of touchscreen devices in early childhood education. Moreover, this study can lend visibility to the current trends of using touchscreen technologies in early childhood educational research. The analysis of early childhood research using touchscreens for educational purposes not only helps identify the gaps and trends in the recent evidence but also underpins and informs future research in the area. Moreover, by examining the potential moderating factors affecting young children's learning with touchscreens, this study can help different stakeholders develop a better understanding of the considerations required when aiming for establishing touchscreen technology-enhanced activities/environments. It can give teachers, educators, and policy makers an insight into how to use touchscreen technology to support an enriched flow of learning and enable innovative practices aiming at obtaining both improved learning outcomes and experiences for young learners.

1.7 Thesis Format and Outline

This dissertation takes an integrated article format. The article integrated into this dissertation is an already published paper in the form of a systematic review addressing the effect of touchscreens on early learning, as well as the factors/conditions accounting for the variability in obtaining the optimal learning outcomes during young children's learning with touchscreen devices. Accordingly, the integrated article can well serve as a comprehensive literature review for the current thesis since it depicts the trends of research on touchscreen technology and early childhood learning. Moreover, by giving an exhaustive summary of the scholarly literature targeting the effect of touchscreen technology on early childhood learning and discussing their findings, the integrated article can provide a deeper understanding of the subject under study and address the ‘how’ questions. Last but not least, the integrated article serves as the basis for the identification of the moderating factors analyzed in the meta-analysis section of this thesis.

Regarding this, the present dissertation consists of a systematic review (i.e., the integrated article) and a meta-analysis/systematic review. To give a brief overview of the thesis outline, this section is followed by a literature review (Chapter 2) dealing with technologies and early childhood learning and briefly discussing the research addressing the SAMR model in the context of early childhood education, as well as the previous meta-analyses exploring the topic under study. The integrated paper is presented successively in Chapter 3 to both cover the literature about the learning impact of touchscreens and serve as a basis for the meta-analysis. The integrated study is presented in the form of an individual ‘stand-alone’ study, containing its different sections, including its own introduction, literature review, methodology, results, discussion, and reference list. Chapter 4 discusses the research methods adopted for the implementation of the meta-analysis by giving detailed information about the methodological framework, searching strategies, data extraction/screening process, and data analysis methods. Chapter 5 presents the results of the meta-analysis/systematic review based on the research questions. Chapter 6 discusses the findings of the meta-analysis/systematic review. This chapter also connects the two studies by reviewing and interpreting the findings of the integrated study and the current meta-analysis based on the broader literature. The major findings and conclusion of the study are addressed in Chapter 6. This chapter also includes the limitations and pedagogical implications of the study, as well as recommendations for future research.

Chapter 2

2. Literature Review

2.1 Early Learning and Literacy

Early childhood education, encompassing all forms of formal and informal education from birth through 8 years of age, is considered a critical building block of child development given its fundamental effect on a child's future accomplishments and success (UNESCO, n.d.). This education has a rich and complex background and long-established history. Over centuries, lots of philosophers, educators, and psychologists have targeted early learning with the aim of uncovering the pedagogical dynamics and strategies that can improve young children's learning (Cubelic, 2013). Accordingly, early childhood education has been affected by various perspectives throughout history.

The constructivist scholars' advocacy of shifting the instructional focus from teachers to learners has probably induced one of the largest effects on early childhood education by defying rote learning and memorization and encouraging active learning through meaning making, inquiry, and authentic activities. This emphasis on active learning can be well responded by technology since it can establish learning environments that are actively engaging for young learners through facilitating interactive and multimodal learning activities. The advocacy of the National Association for the Education of Young Children (NAEYC, 2012) for the intentional use of developmentally appropriate technology-based activities in early childhood education is a good proof to this claim. The NAEYC (2012) dismissed the emphasis on drilling/practice and the focus on isolated skill acquisition and rather encouraged the establishment of opportunities facilitating critical thinking and exploration and the inclusion of meaningful learning activities that are relevant, interactive, and hands-on. The introduction of technologies to educational settings was a major step toward achieving such goals. Technologies give the teacher the chance to create learner-centered environments and new learning opportunities tailored to students' learning styles and preferences (Lee et al., 2018). However, the use of technologies in early educational settings has been always subjected to debates and skepticism (Alper, 2011; Blackwell, 2013; House, 2012; Lindahl & Folkesson, 2012; Plowman & McPake, 2013).

2.2 Inconsistent Evidence: Two Sides of the Spectrum

The opponents of using technologies in early childhood learning consider technology to be developmentally inappropriate for young children (Ahearne et al., 2016; Dauw, 2016; House, 2012) and believe that too much screen time can result in sensory overload (House, 2012; Lauricella et al., 2015; OECD, 2019), which, in turn, leads to poor concentration and attention difficulties (Cordes & Miller, 2000; House, 2012). Moreover, some other opponents point to the health issues, such as visual difficulties (Cordes & Miller, 2000) and muscular-skeletal injuries (Cordes & Miller, 2000; Plowman & Stephen, 2003), which might emerge as a result of overusing technology. The vulnerability of young children to inappropriate or violent contents and media messages (Cordes & Miller, 2000; Lieberman et al., 2009) that might lead to aggression and anti-social behaviors is another argument highlighted by those discouraging the use of technology for early learning (Anderson & Bushman, 2001; Cordes & Miller, 2000; Garrison & Christakis, 2012; Vijakkhana et al., 2015).

However, the proponents of using technology in early educational settings posit that technology can improve child learning if used in a thoughtful and developmentally appropriate manner (Blackwell, 2013; Blackwell et al., 2014; Lindahl & Folkesson, 2010; Parette et al., 2010; Plowman et al., 2011). It is argued that technology can enhance young children's engagement and motivation (Bird & Edwards, 2015; Burnett, 2010; Churches & Dickens, 2012; Lindahl & Folkesson, 2010; Molnar, 2013) and support the development of social skills through encouraging collaboration (Alper, 2011; Cicconi, 2014; Shifflet et al., 2012).

Moreover, the advocates of this side of the argument underscore the fundamental role of technologies in providing the educators/teachers with valuable tools to create learner-centered learning activities/environments (Blackwell, 2013). The high applicability of technologies in supporting children with special needs and disabilities is another advantage noted by the proponents of using technology in early educational settings (Cordes & Miller, 2000; Hutinger & Johanson, 2000; Muligan, 2003). In addition, it is argued that children's interaction and experiences with technologies can facilitate the development of the essential technology skills they require in their future careers (Hillman & Marshall, 2009; Rosen & Jaruszewicz, 2009).

The growing prevalence of digital technologies in our surroundings and the increasing uptake of these media by young children have made it implausible to think of education without technologies. We need to accept that technology is here and is going to stay in every aspect of our everyday life and educational experiences. Accordingly, there is a growing need for shifting our focus from whether technology should be utilized in early educational settings to how it should be used and benefited in a way that can transform young children's learning experiences and outcomes and induce the most desirable effects (Ko & Chou, 2014; Parette et al., 2010; Rosen & Jaruszewicz, 2009). This urge for shifting the focus has directed the educators' and policymakers' attention to the question of how to best incorporate digital technologies into early childhood settings (Plowman et al., 2012).

Accordingly, these attempts have led to the development of recommendations on the thoughtful selection, use, and integration of technologies by attentively considering their features and design. For instance, the practitioners are suggested to take into account if a technology that is going to be integrated into pedagogical approaches encourages creativity, engagement, and curiosity, stimulates social interaction, and creates an authentic learning experience (McManis & Gennewig, 2012; NAEYC & the Fred Rogers Center, 2012; Plowman et al., 2012; Rosen & Jaruszewicz, 2009).

2.3 Touchscreens and Early Learning

For years, educators/teachers have watched for emerging technologies to facilitate the enhancement and transformation of learning processes that allow for focusing on each student, enhancing their motivation and learning, and supporting the development of their 21st century skills (Geer et al., 2017). Touchscreens (e.g., iPads, tablets, and smartphones) as intuitive technologies have been identified to have the potential to significantly affect learning in K-12 settings (Johnson et al., 2014). The intuitive features of touchscreens have encouraged the increasing use of these devices for young children both at home and educational environments (Dunn et al., 2018; Flewitt et al., 2015; Marsh et al., 2015; Neumann & Neumann, 2017). The tactile interface of the touchscreens has removed the developmental barriers (e.g., fine motor skills and eye-hand coordination required to manipulate a keyboard and mouse) young children used to face when using computers (Lovato & Waxman, 2016). Moreover, the portability, ease of use, long battery life, and affordable hardware and software are among the other features of touchscreens that have increased the incorporation of these devices into early childhood settings (Geer et al., 2017). Touchscreens are well responsive to the inclination towards the personalization of learning (Johnson et al., 2012), as well as enhanced flexibility and access, by enabling the learners to take the ownership of their learning (Willocks & Redmond, 2014).

There is a growing body of research targeting touchscreen affordances for early learning, such as improved motivation, engagement, collaboration, communication, and social interaction (Bird & Edwards, 2015; Burnett, 2010; Churches & Dickens, 2012; Molnar, 2013; Murray & Olcese, 2011), as well as instant access to resources (Alyahya & Gall, 2012; Barnes & Herring, 2011). However, similar to other educational technologies, the literature on the effect of touchscreens on early learning contains inconsistent findings. Although most of the studies have reported the higher effectiveness of touchscreen-enhanced activities/approaches, compared to the more traditional approaches, there are still some studies indicating no difference between the two or even the negative effect of touchscreen-based activities on young children's learning (e.g., Bebell & Pedulla, 2015; Bullock et al., 2017; Moyer-Packenham et al., 2015, 2016). These inconsistencies in the literature are indicative of the presence of other factors moderating the effect of early learning with technology. Accordingly, the consideration of different potential moderators in the present study can make a significant contribution to this domain by giving insight into the factors accounting for achieving more desirable outcomes when learning with touchscreens.

2.4 SAMR Framework

The SAMR model was originally established by Puentedura (2006) as a framework for encouraging the adoption of technologies in different instructional settings and supporting the instructional designers and teachers in creating improved learning experiences by effectively integrating technology into their pedagogical practices. The SAMR framework also equips the educators with a tool to evaluate and categorize the level of an integrated technology. Although targeting all kinds of technologies, this model has been specifically suggested by several researchers to be helpful for evaluating mobile learning (Fabian & Maclean, 2014; Hockly, 2013; Pfaffe, 2017; Romrell et al., 2014; Woodruff & Wagner, 2019).

Romrell et al. (2014) used the SAMR model to evaluate the literature on mobile learning in higher education and categorize the instructional activities across the four levels of this framework. They found this model helpful for evaluating mobile learning. Accordingly, they recommended this framework not only for evaluative purposes but also for designing mobile learning activities and facilitating the transformation of learning. In another interventionist/action study aimed at estimating the benefits and potential drawbacks of using mobile technologies for pedagogical purposes in a tertiary educational context, Fabian and Maclean (2014) used the SAMR model to analyze the tablet-based activities carried out by college students in different subject areas. They identified that mobile learning activities were performed at all four SAMR levels (i.e., both enhancement and transformational levels) and acknowledged the suitability of tablet devices, equipped with multiple features and functions, for the implementation of learning activities that once used to be unrealistic or infeasible.

The SAMR framework has been also used to gauge the level of technology integration in middle school contexts. In a randomized controlled trial, Fabian and Topping (2019) utilized the SAMR model to categorize the mobile learning activities of grades 5 and 6 students during mathematic interventions. To this end, they performed several observations to map the type of mobile-learning-based pedagogies employed by instructors across the four levels of SAMR model. In the mentioned study, the majority of the mobile-enhanced activities were under the augmentation or modification spectrum rather than the redefinition level. The authors reported that the mobile-enhanced learning activities were more fruitful when being administered at the modification level, compared to the augmentation level.

Geer et al. (2017) also used the SAMR model to investigate the effect of iPads on the changes in the pedagogical practices of four middle schools. Their results were suggestive of the incidence of some modifications in teachers' pedagogy, which had resulted in improved collaboration, communication, self-reliance in students, and the development of authentic experiences. However, the authors pointed to the need for more time and professional learning to bring about a transformation in pedagogical approaches across schools. This need for giving more attention to creating more transformative learning experiences was also highlighted by Pfaff (2017) who reported the higher adoption of mobile learning at the enhancement levels rather than the transformative levels among the secondary school teachers.

As the literature review indicates, most of the studies adopting the SAMR framework have targeted the evaluation of technology integration in tertiary education settings (e.g., Burden et al., 2019, Fabian & MacLean, 2014, Romrell et al., 2014; Woodruff & Wagner, 2019) and secondary education contexts (e.g., Fabian & Topping, 2019; Geer et al., 2017; Pfaffe, 2017). To the best of my knowledge, there are only two studies using this framework for planning/categorizing learning with technologies in the context of early childhood education. Lantz et al. (2020) employed the SAMR framework to explore the approaches through which digital storytelling can transform the way young children develop literacy skills. Drawing on the SAMR model, they recommended some developmentally appropriate strategies and practical tips for the integration of digital storytelling into literacy instruction in PK-3 educational settings.

In the other study, which is a systematic review, Crompton and Burke (2020) adopted the SAMR framework to categorize the mobile learning activities employed in published empirical research to explore if mobile devices are used to transform learning in PK-12. Regarding the Pre-K and elementary grade levels, they reported that researchers investigated the use of mobile technologies most often at the augmentation level, denoting that at this grade, learning with technology is only being enhanced, not transformed. The gap in the literature using the SAMR framework to specifically explore the use of touchscreen technologies, as highly popular educational media, in early learning highlights the need for research targeting this domain. Accordingly, the present research would be the first attempt using the SAMR model to provide an overview of the status of how touchscreens are used in early childhood education (i.e., whether touchscreens are used for the enhancement of early learning or its transformation).

Most of the studies in the literature have used the SAMR model as a tool to estimate how technologies add value to non-technology-based learning activities by ideally transforming learning. The taxonomic structure of the SAMR model is representative of the idea that an effective integration of technologies is accomplished by making transitions to the higher levels of the SAMR model (i.e., modification or redefinition) and transforming the way learning is occurring (Puentedura, 2014). This model is established on the premise that better learning outcomes are achieved at the modification and redefinition levels (i.e., the transformational levels) of the SAMR. However, one point that needs to be considered is if the transformative use of technologies necessarily results in better learning outcomes, especially in early learning. Thus, this study attempted to find the answer to this question by evaluating how the effect of touchscreens on early learning may vary when used at each of the substitution, augmentation, modification, and redefinition levels.

Despite the usefulness of the SAMR framework, there are some criticisms about the lack of transparency and limited practical examples on how to interpret and apply this model, which can result in confusion and misinterpretation (Hamilton et al., 2016). In order to avoid this issue, the expanded definition of SAMR levels (Crompton & Burke, 2020) was used. Based on this expanded model, the SAMR levels are defined as follows:

Substitution: Students/teachers produce the same type of product and/or follow the same learning process that can be achieved if digital technology was not used.

Augmentation: Digital technology is used by students/teachers to make small adjustments to products and/or learning processes that cannot be achieved without the use of digital technology.

Modification: Digital technology is used by students/teachers to either create products that cannot be accomplished without digital technologies or be involved in learning processes that cannot be accomplished without digital technologies.

Redefinition: Digital technology is being used by students/teachers to both create products and learning processes that cannot be accomplished without digital technologies.

2.5 Previous Meta-analyses

The literature contains several meta-analysis studies that have either investigated the impact of a specific digital technological medium, such as multimedia-enhanced storybooks (e.g., Anguiano, 2020), mobile and information technologies (e.g., Mavi & Erbay, 2021), and educational apps (e.g., Kim et al., 2021), or generally explored the effect of a wide set of technological tools (e.g., Chauhan, 2017) on childhood learning. However, the review of the literature only revealed one meta-analysis carried out by Xie et al. in 2018 that had specifically addressed the impact of touchscreen technology on early learning. In the mentioned study, the researchers addressed the overall learning effect of touchscreens on young children aged 0-5 years. The results, which were based on 36 empirical studies, were indicative of the significant effect of touchscreens on early learning performance. Additionally, learners' age, comparison group, learning material domain, and experimental environment were found to significantly moderate the impact of touchscreen technologies on young children's learning. The scarcity of meta-analytic studies specifically targeting the effect of touchscreens in the context of early childhood learning urges the need for the implementation of more studies to both ascertain the consistency of findings and provide more up-to-date data on this domain. Accordingly, the present meta-analysis can add to the literature and contribute to the existing findings by establishing the results based on a wider set of studies and more recent data.

Chapter 3

3. Systematic Review Paper

What Is the Effect of Touchscreen Technology on Young Children's Learning?: A Systematic Review

Abstract

This systematic review provides an overview of existing evidence regarding the effect of touchscreen technology on young children's learning. Using PRISMA principles, we identified 53 studies in our review. The literature generally advocated positive effects of touchscreen devices on young children's learning with 34 studies reporting positive effects, 17 studies obtaining mixed findings, and 2 articles reporting negative effects. The factors/conditions of touchscreens affected young children's learning were classified into five categories including app features/contents, applied pedagogical approach, adult mediation, instructional grouping, and child age and previous experience/familiarity with touchscreens. Our findings have implications for different stakeholders by giving them insights into the impact of touchscreen devices on young children's learning under different conditions.

Keywords Touchscreen technology, Early childhood learning, Young children, A systematic review

3.1 Introduction

Technological advancements in the 21st century have created a remarkable shift in learning experiences for young children (Kim et al., 2021; Kucirkova et al., 2019). The ubiquity of technologies in our daily lives has exposed children to a wide array of digital devices from an early age. This high exposure has turned the 21st century children to digital natives who naturally use technologies as the components of their everyday lives in both formal and informal settings (Sharkins et al., 2016).

According to a nationwide survey conducted in the U.S. in 2017, 98% of children aged 0-8 years had access to mobile devices in their home environment, and 42% of them owned their personal tablets. These rates indicate the high popularity of digital devices, especially touchscreen devices, among young children (Holloway et al., 2013).

The lightweight design and tactile-based digital interface of touchscreens allow even very young children to interactively engage with the digital content (Plowman et al., 2012). Moreover, the potentials of touchscreens to facilitate personalized, flexible, and mobile learning experiences, as well as individualized assessment and rich communication (Mehdipour & Zerehkafi, 2013), have led to the introduction of these devices into school settings for educational purposes (McLean, 2016). The increasing uptake of touchscreens by young children both in formal and informal settings highlights the importance of giving special consideration to the effects of these technologies on early childhood learning.

To provide an overview of the existing evidence regarding the impact of touchscreen devices on early childhood learning and shed light on the current research trend in the field, it is required to conduct a systematic review. In our systematic review, the research questions include: (1) What are the trends of research on touchscreen technology and early childhood learning? 2) What is the effect of touchscreen technology on early childhood learning?, and 3) What factors/conditions account for the variability in obtaining the optimal learning outcomes during young children's learning with touchscreen devices?

3.2 Literature review

Technologies have an undeniable role in twenty-first century education. Further, since the twenty-first century children are experiencing a fast-changing era of digital technologies and are grown up as digital natives, the consideration of these shifts in education is a matter of significant importance, especially in early childhood literacy. The high exposure of the young generation to a wide array of technologies has made a great shift in their learning experiences and resources. Thus, there is a need for the reconsideration of the traditional model of education involving the transmission of knowledge (Harrell & Bynum, 2018) to keep this young net generation engaged and equip them with 21st century skills.

Constructivism has been widely recognized as a framework to address the importance of active participation of the learners including young children in a discovery-oriented process within an authentic meaningful setting (Bruner, 1977). To support these main tenets of constructivism, affordances of technologies has been reported in the literature (e.g., Reeves et al., 2017). The integration of technology into educational settings is ascribed to the process of utilizing the potentials of technological tools and resources to improve and support the teaching and learning processes.

Touchscreen devices provide unique opportunities for learning via physical experience and/or actions by allowing for sensorimotor interactions and physical manipulation of the items displayed on the screen (Wang et al., 2016). During the past decade, there has been a growing body of studies aiming to explore the impacts and potentials of touchscreen devices for young children's learning. Cordes and Miller (2000) argued that digital technologies could negatively affect children's academic achievement and communication with other children. They noted that the use of digital technologies by young children could influence their intellectual skills, such as creativity and language development, resulting in poor concentration and imagination.

Concerns about the screen time and nature of digital media (e.g., violent contents) and their effects on children's sleep quality and behaviors are also addressed in the literature (Garrison & Christakis, 2012; Vijakkhana et al., 2015). The American Academy of Pediatrics (2009) has warned about the exposure of young children to violent content through digital technologies and their consequences, such as "aggressive behavior, desensitization to violence, nightmares, and fear of being harmed" (p. 1495). Screen time has been also reported to be weakly associated with children's mental well-being (OECD, 2019). However, a large body of research investigating the impact of screen time on well-being among children has adopted a correlational design, which cannot guarantee a cause-and-effect relationship.

It should be noted that the literature mostly entails concerns about the impact of digital technologies. This is while touchscreens owing to their affordances and features cannot be considered the same as other common digital technologies. As acknowledged by OECD (2019), "active interaction with touchscreens can generate dynamic stimulation, and, if used appropriately, may be just as engaging and cognitively stimulating as traditional toys or books" (p. 45). The personal, interactive, and mobile nature of touchscreens has made these devices promising tools for educational purposes. Touchscreens have been argued to have the potential to enhance collaboration, motivation, engagement, social interaction, multimodal literacy, and individualized learning (Bird & Edwards, 2015; Burnett, 2010; Churches & Dickens, 2012). Moreover, the ubiquity of touchscreens enabling access to educational information anywhere and anytime has improved the learning experiences for young learners (Johnson et al., 2011).

In short, these studies have reported a mixed set of findings. While several studies have dealt with the harms of these learning media regarding learning, development, and health issues, numerous others have reported the positive potentials of these devices to improve children's learning experiences and development (e.g., Miller, 2018). In other words, despite the growing trend of using touchscreen technologies in teaching and learning, the effective integration of touchscreen technologies into early childhood education has remained complex.

Therefore, the variability of research findings targeting the impacts of touchscreen devices on early childhood education necessitates the implementation of a review to provide different stakeholders with a general view of the effect of these educational tools on young children's learning from different perspectives. There are several review studies which investigated the impact of digital technologies on different aspects of early childhood learning, such as cognitive, social, and emotional development (e.g., González-González et al., 2019; Hsin et al., 2014). However, we noticed that there are only few review studies specifically investigating the effect of touchscreen technologies on early childhood learning outcomes.

For example, Herodotou (2018b) reviewed 19 studies examining the touchscreen learning effects on children aged 2-5 years and reported a generally positive effects on literacy, mathematics, science learning, problem-solving skills, and self-efficacy. In addition, Xie et al.'s (2018) meta-analysis reviewed 36 empirical articles on the learning achievements of touchscreen mobile devices for young children aged 0-5 years. Their results indicated a positive effect moderated by child's age, learning domain, experimental environment, and comparison group. Except these works, there is still a need for a more recent comprehensive review of the effects of touchscreen technologies on early childhood education.

3.3 Method

To address these issues, we employed a systematic review to review the effect of touchscreen technologies on early childhood learning. A systematic review facilitates the synthesis of data in an unbiased and impartial manner. Accordingly, it has a set of studies to achieve pre-specified conclusions since it involves a review of the relevant literature employing explicit, systematic, and accountable methods (Gough et al., 2012). To answer the research questions, both aggregative and configurative review methods were employed. An aggregative review approach facilitates responding to tightly specified questions using quantitative methods and empirical observations, while a configurative method is suitable for answering more open questions using qualitative data (Gough et al., 2012). The former method is used for the first and second research questions, whereas the latter well suits the third question.

Although the PRISMA model has been commonly applied in the field of health sciences, it has been also adopted in systematic reviews in the field of educational technology (e.g., Boon et al., 2020; Crompton & Burke, 2020). Using PRISMA principles (Liberati et al., 2009), the relevant studies published between 2010 and 2020 were systematically searched using different databases, including the Web of Science, ERIC, EBSCO, JSTOR, and Google Scholar, as well as university libraries. We used the following keywords: "technology", "touchscreens", "iPads", "tablets", and "mobiles" in combination with "early childhood learning", "child learning/education", "preschoolers", and "pre/kindergarteners". In addition, the reference lists of the included studies were manually searched to identify the additional relevant records.

The peer-reviewed studies meeting the following inclusion criteria were included in our systematic review: presenting quasi-experimental or empirical data; involving children aged 2-8 years; investigating the use of touchscreens in school or home setting; examining the educational outcome of touchscreen technologies in early childhood learning; using a systematic approach to measure the outcomes; being published in English language; and being published between 2010 and 2020. The reason for the selection of 2010 as the starting point was that it marks the date that iPads, as significant touchscreen technologies, were introduced to the market. The exclusion criteria included inadequacy of data, secondary resources (e.g., book chapters, meta-analysis and systematic reviews, and magazines), and non-availability of the full-text version. The initial search involving screening the titles and abstracts resulted in the retrieval of 1,065 studies.

The studies identified via database searching (n = 1,065) were subjected to further screening. After the removal of duplicate articles (n = 36), the abstracts of the articles were screened against the inclusion criteria. In case the abstract had inadequate information to ensure article eligibility, the method section of the study was investigated. As a result of abstract screening, a total of 940 cases were excluded from the study due to their study design, investigation of non-touchscreen technologies, participants' age range, examination of participants or adults' perceptions of technology use, investigation of touchscreens for assessment purposes, and examination of touchscreens for early childhood educators. After reviewing the full-text version of the articles, 46 studies were found eligible to be included in the study. After removing the duplicates (*n* = 36) and screening the articles against the eligibility criteria (*n* = 940), the manual searching of the reference lists of the included articles resulted in the addition of 7 more studies. Finally, 53 articles were included into the review process. The process of article selection is illustrated in a PRISMA flowchart presented in Figure 1.

The quality of the included studies was assessed by the two authors using the CASP tool with an inter-rater agreement of 98%. According to Long et al. (2020), this tool provides a good judgment of the procedural aspects and details of the research, compared with different appraisal techniques. Accordingly, we evaluated each study against such criteria as methods, rigor, credibility, and relevance. To guarantee precision, an external reviewer was employed to assess the quality of almost a third of the studies (*n* = 18). This assessment resulted in an agreement of 98%, which indicates a good inter-rater agreement. A consensus on discrepancies was reached through discussion between the raters.

After reading each article thoroughly, the following information was identified and transferred to the generated Excel sheets as recommended by Miles et al. (2014): publication year, research setting, research objective, research design and method, sample size, participants' age, learning outcome (i.e., dependent variable), intervention session/duration, type of touchscreen technology, and key findings. To extract data from the eligible studies, we developed a codebook on an Excel sheet as a guide throughout the data extraction procedure. The two authors independently extracted data in separate Excel sheets to minimize bias and error. Any discrepancy was discussed until reaching a consensus.

4. Findings

4.1 Trends of Research on Touchscreen Technology and Early Childhood Learning

With respect to the publication year of the included studies within the 10-year period (2010-2020), the majority of the research (85%) has been conducted within the recent 5 years (2015-2020). Regarding the geographical distribution, over half of the studies (*n* = 30, 57%) had been conducted in North America, including US (*n* = 26, 49%) and Canada (*n* = 4, 8%). Furthermore, 17% of the reviewed studies (*n* = 9) had been performed in the European

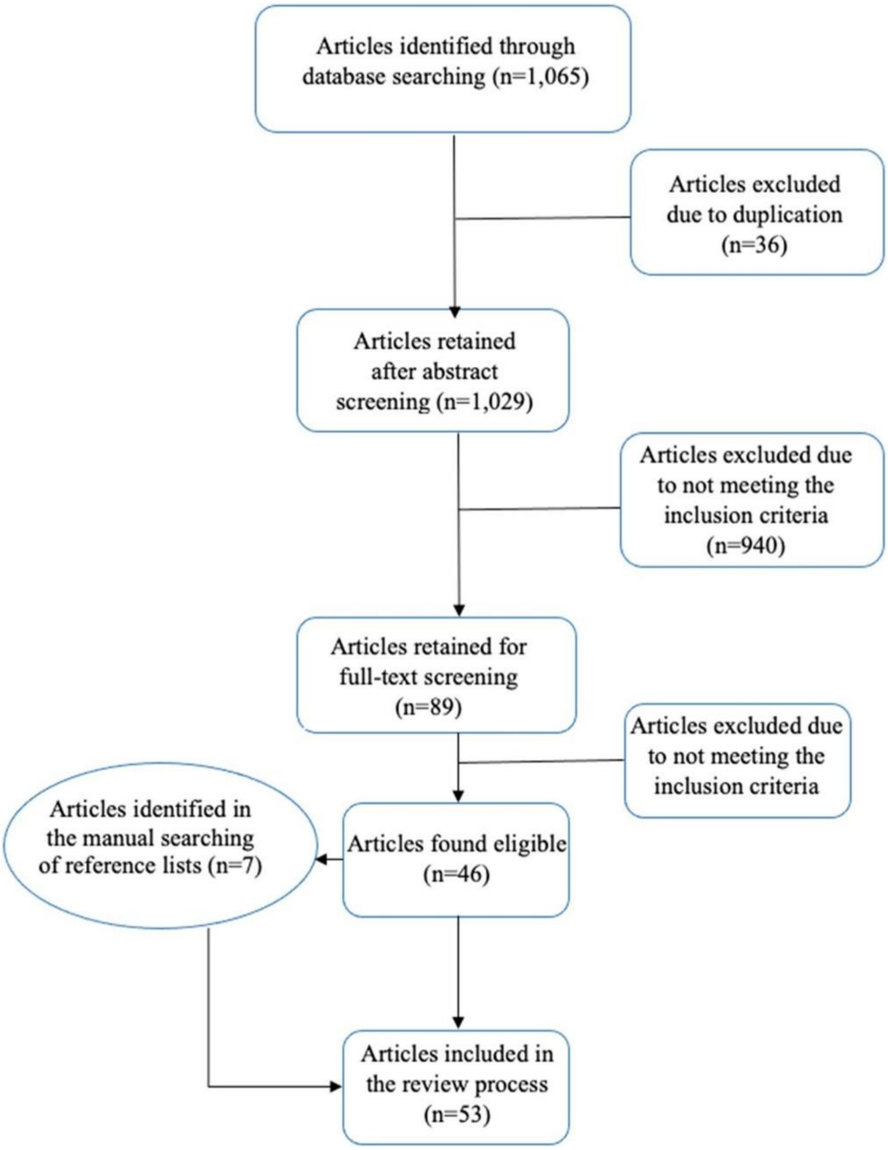

Figure 1: PRISMA Flowchart of the Study Selection Process

performed in the European countries, including Greece (n = 2), France (n = 1), Sweden (n = 1), Netherland (n = 2), Switzerland and Germany (n = 1), United Kingdom (n = 1), and England (n = 1). The Asian (Dubai [n = 1], Indonesia [n = 1], Japan [n = 1], and China [n = 2]) and Australian studies also constituted 9% and 1.6% of the articles, respectively. Only one study was conducted in South America, Argentina, and there was no study having been performed in Africa. Moreover, the geographic region was not clearly indicated in five articles.

Out of the 53 reviewed articles, 36 cases had a true experimental design, and the rest were either quasi-experimental (n = 16) or pre-experimental (n = 1). The sample size largely varied across the studies, ranging from 3 to 389 cases. A total of 4,387 children had been investigated in the reviewed articles. Furthermore, the age groups of 4 and 5 years equally had the highest frequency. Given the nature of the included studies, each study involved at least one intervention, the effect of which was compared between or within participants. Almost one-third of the studies (*n* = 19) were limited to one or two interventional sessions, lasting 5-40 min. In addition, 9 studies involved 3-10 sessions (5-40 min). However, there were also studies with 11-20 interventional sessions (*n* = 5; lasting 10-40 min) and 21-60 interventional sessions (*n* = 6; lasting 10-40 min) performed throughout the school year/ semester as an integral part of the formal curriculum (e.g., Mowafi & Abumuhfouz, 2021). The number of the interventional sessions was not clear in 14 studies.

The reviewed studies addressed the effect of touchscreen devices on different subject domains, skills, and learning outcomes. The majority of the articles targeted one specific subject domain or skill (*n* = 40), while others (*n* = 13) investigated a combination of both or more than one subject domain. The subject domains investigated in the articles included mathematics (*n* = 19), literacy (*n* = 13), science (*n* = 5), and art (*n* = 2). The rest of the articles (*n* = 14) addressed other skills or a combination of different domains and skills (e.g., examining both mathematic skills and literacy).

All articles, including these targeting one domain or multiple domains, mathematics (*n* = 24) and literacy (*n* = 24), were equally the most frequently investigated subject domains. Further, the skills addressed in the reviewed studies were executive functioning, prosocial skills, and imitation skills (*n* = 1, for each). The other learning-related outcomes examined were engagement (*n* = 5), attention (*n* = 2), and motivation/self-efficacy (*n* = 1). Regarding the findings of studies, most of the studies (*n* = 34) reported the positive learning effects of using touchscreens on young children's learning. While 17 studies obtained mixed findings (a combination of negative, neutral, and positive effects) with mostly neutral and positive findings, there were only two articles reporting purely negative learning effects.

4.2 Effect and Factors of Touchscreen Technology on Early Childhood Learning

4.2.1 Literacy

The effect of touchscreen technologies on literacy development among children aged 2-8 years was examined in a total of 24 studies, including 19 experimental studies and 5 quasi-experimental studies. The reading literacy domain investigated in the articles included letter learning, phonological awareness skills, decoding (Larabee et al., 2014), reading fluency

(Puspitasari & Subiyanto, 2017), story comprehension, vocabulary (Walter-Laager et al., 2017), print concepts, letter-sound knowledge, numeral letters, and word recognition. Neumann (2018) and Patchan and Puranik (2016) noted the impact of a touchscreen literacy program on young children's emergent writing literacy, particularly print concepts and writing names, letters, numbers, and uppercase letters.

A total of 10 studies examined the effect of digital books on early childhood literacy skills. These studies presented a mixed set of findings regarding the impact of touchscreen books on literacy skills. Most of the studies confirmed the effectiveness of digital books on comprehension. While some studies indicated the superiority of eBooks over print books in improving comprehension (e.g., Shirley, 2018), other studies reported the effectiveness of these modern tools was equal to those of the traditional tools. For instance, in a study comparing story comprehension of 4-year-old children using e-books and print books, O'Toole and Kannass (2018) found that the touchscreen books were as supportive as the traditional print books for the study participants. Similarly, by comparing the effect of a digital storybook with a print book read by a teacher for 4- to 5-year-old preschoolers, Zipke (2017) observed no difference between the two groups in terms of story comprehension.

However, Parish-Morris et al. (2013) argued that these results may be age-dependent effects. Also, they obtained relatively different results compared with previous studies (Xu et al., 2021), which indicated the positive effects of eBooks on lower level of comprehension skills (e.g., character and event identification) but the negative effects on the higher level comprehension skills (e.g., story structure and details). This result was ascribed to the presence of distracting features (e.g., games, sound effects, hotspots) in the digital books in terms of the flow of the story.

Drawing upon this age-dependence hypothesis, Piotrowski and Krcmar (2017) investigated how hotspots in eBooks as interactive features of touchscreens positively affected the attention and story comprehension of a group of Dutch preschoolers aged 2-5 years. Also, using eBooks purposefully embedded with animations and interactive features congruent with the plot, Zipke (2017) observed that the children using an eBook with more interactivity features developed higher level story comprehension than those working with an eBook equipped with few interactivity features. However, it should be noted that the quality of the hotspots and their relevance to the story flow determine their contribution to child's story comprehension. The inclusion of irrelevant hotspots or games could lead to cognitive overload, thereby inhibiting child's story comprehension (Bus et al., 2014). For example, Krcmar and Cingel's (2014) study reported that a digital book caused an increased cognitive load on the child's story comprehension.

Regarding other literacy domains, all other studies addressing eBooks, except one, indicated the higher effectiveness of touchscreen books over the print books in terms of vocabulary knowledge (Teepe et al., 2017), reading ability (Masataka, 2014), and word recognition (Zipke, 2017). By examining the influence of book type (i.e., digital or print) on alphabetic knowledge among 4-year-old children, Willoughby et al. (2015) reported a similar improvement in their phonological awareness, letter-name, and letter-sound knowledge.

Nine studies targeted the comparison of the effectiveness of iPad versus non-iPad resources in early literacy skills. In a quasi-experimental study, Reeves et al. (2017) compared a set of literacy skills (i.e., phonological awareness, print knowledge, vocabulary knowledge) between two groups of preschoolers exposed to either iPads with guided instruction or a traditional Pre-K curriculum without iPads. The results of their 7-month study revealed a significant improvement of phonological awareness among the children using iPads although there was no significant difference regarding print and vocabulary knowledge in the two groups.

Several studies investigated the efficacy of touchscreens in improving literacy learning achievement of students with special needs (e.g., sight word fluency, see Musti-Rao et al., 2015). Chai (2017) observed the impact of a researcher-developed iPad app in enhancing phonological awareness among young children with mild developmental delays. D'Agostino et al. (2016) study also noted the effectiveness of an iPad app in word sounds, letter identification, text reading, vocabulary, and concepts about print among 6- to 7-year-old children identified as struggling readers. Further, Musti-Rao et al. (2015) and Zipke (2017) reported the impact of iPads on fostering independent learning in children's literacy development.

4.2.2 Mathematics

A total of 24 articles, with experimental (n = 14), quasi-experimental (n = 8), and pre-experimental (n = 1) designs, addressed the impact of touchscreen use on children's mathematics learning compared to traditional manipulatives. The investigated mathematics skills included counting and sorting (e.g., Brown & Harmon, 2013; Outhwaite et al., 2019), computational skills (e.g., Disney et al., 2019), numeracy concepts (e.g., Miller, 2018; Spencer, 2013), spatial relationships and patterns (e.g., Mowafi & Abumuhfouz, 2021), number-object correspondence and comparing quantity tasks (e.g., Schacter & Jo, 2016), addition and subtraction (e.g., Outhwaite et al., 2019), time (e.g., Wang et al., 2021), and subitizing (e.g., Broda et al., 2019).

The majority of the selected literature (*n* = 22) reported the effectiveness of touchscreen interventions by comparing children's mathematics achievement in traditional non-touchscreen methods (see Miller, 2018; Reeves et al., 2017). For example, Schacter and Jo (2016) investigated mathematics performance of 273 preschoolers aged 4-5 years after attending tablet-based math instructions for 15 weeks. They demonstrated an almost 12 times higher gain in their mathematics skills (e.g., numeral sequencing, cardinal principle, comparing quantities, matching numerals to quantities), compared to their counterparts in the control group of regular mathematics curriculum.

After the 4-month intervention, the results obtained by Mowafi and Abumuhfouz (2021) also indicate the higher efficacy of the touchscreen-based mathematics lessons over the existing mathematics instruction in improving young children's understanding of numeracy and spatial relationships and patterns. This finding is in line with the results reported by Disney et al. (2019), who investigated the impact of iPad-based games on numeracy learning of 3- to 4-year-old children who attended a 2-week intervention implementing five developmentally appropriate iPad numeracy apps. The use of iPads in a play-based setting resulted in the enhancement of children's numeracy scores. Furthermore, Spencer (2013) obtained the long-term impact of iPad in improving young children's numeracy learning.

Broda et al. (2019) allowed a group of 18 4- to 5-year-old preschoolers to independently interact with an app targeting early number sense for 4 weeks. Their results demonstrated that preschoolers' interactions with the touchscreen app resulted in a significant increase in their speed and accuracy when performing subitizing tasks. This improved accuracy in responding to mathematics problems was also observed in a study conducted by Shanley et al. (2020) when the instructional cueing and self-regulation supports were added to the tablet-based intervention for 5- to 6-year-old children with mathematics difficulties.

On the contrary, there are the increased number of mixed findings (*n* = 4) on the positive, neutral, and negative effects of touchscreen devices. Mattoon et al.'s (2015) study reported the impact of touchscreens on the computational skills of 4- to 5-year-old preschoolers compared to traditional manipulatives such as plastic bears, candy hearts, cubes, and dice during math instruction. The results of the Early Mathematics Ability test administered after the 6-week intervention revealed a significant increase in the computational skills of both groups.

Several studies involved the comparison of the effect of different types of digital technologies (e.g., tablets, computers; n = 2) and modes with touchscreens (e.g., playing, watching; n = 3), or specific touchscreen app with other apps (n = 2) on young children's mathematics learning. The results of the studies comparing the impact of tablets with computers advocated the higher contribution of tablets to the enhancement of young children's mathematics learning. For instance, Papadakis et al. (2016) compared the impact of tablets with computers on mathematics learning of 256 children aged 4.5-5.5 years during a 14-week intervention. Although the children in both groups showed a progress in their mathematical skills, the higher improvement in the tablet group was reported.

Drawing upon this finding, Papadakis et al. (2018) further investigated the comparison of the impact of tablets with those of computers on mathematics learning of a larger group of students (N = 365) in three groups (i.e., tablets, computers, control) during one academic year. The tablet group obtained the highest score of mathematical comprehension, followed by the computer group, and then control group. This is likely because touchscreen devices revealed such affordances as higher portability, personalization, haptic feedback, and functionality, resulting in facilitating the implementation of a wide set of pedagogical activities.

The examination of the studies also reveals that the comparison of modes of playing touchscreens with modes of watching touchscreens showed the interactivity feature effect of the touchscreen apps on near and far transfer of the mathematic concepts. For example, in Aladé et al.'s (2016) study, 60 preschool students in two intervention groups and one control group were exposed to the same app content by either playing an interactive tablet-based game or viewing a non-interactive video. Participants in the intervention groups outperformed those in the control group in the overall knowledge transfer task. However, the follow-up analysis of the overall score according to difficulty levels of the transfer task revealed mixed findings. Although participants playing with interactive games performed better in near-transfer tasks, those viewing the non-interactive videos showed better outcomes in far-transfer tasks. The authors noted that this finding may be related to the similarity between the tasks used during training and testing. They concluded that interactivity might be effective in transfer tasks that are highly similar to the training tasks.

This finding is consistent with the results reported by Schroeder and Kirkorian (2016). They investigated the effect of game interactivity (i.e., watching or playing) and character familiarity in young children's mathematics learning (i.e., numerical cognition) and learning transfer. The 3- to 5-year-old children played a couple of tablet-based games in either condition of playing or watching. It appears that these games were effective depending on the children's age and the difficulty level of the game regardless of the game interactivity. This transfer of learning using touchscreen devices was also examined by Wang et al.'s (2016) study in which a group of 5- to 6-year-old children (n = 65) learned using one of these tools: an iPad, a toy clock, or a drawing of a clock. The results revealed the efficacy of touchscreens in young children's learning about time. Also, the children exhibited positive transfer of learning from iPad to iPad and physical toy clock. Achieving this transfer of learning was particularly difficult when participants learned the concept of time using a drawing of a clock. These findings could be explained by the presence of similarity between the iPad and the physical toy clock. Wang et al. (2021) also investigated the transfer of learning by comparing iPad with video in teaching the concept of time to 123 preschoolers, resulting in better effectiveness of iPad in participants' understanding of the concept of time and the positive transfer of learning after using iPad.

In most of the selected literature, features of touchscreen devices in affecting children's mathematics learning appear frequently. To identify the efficacy of a tablet app, Math Shelf, in enhancing young children's number sense, Schacter et al.'s (2016) study assessed mathematics learning of 100 low-income preschool children using either the Math Shelf or the most downloaded math apps for preschoolers. Participants in the group of Math Shelf app performed better than the other group. This finding is consistent with the results reported by Brown and Harmon (2013). However, several studies indicate that children's different responses to educational apps depend on children's age (Bullock et al., 2017).

4.2.3 Science

The effect of touchscreens in children's science learning is discussed in 5 studies, resulting in mixed findings. Furman et al. (2019) investigated the impact of touchscreens on science learning of five-year-old children by incorporating tablets into an inquiry-based science teaching approach. After a six-week intervention, significant improvements were observed in science learning for all students in both the tablet and non-tablet groups. The analysis of the reviewed studies also reveals that the learning effect of a touchscreen mobile game in understanding scientific concepts (i.e., projectile motion See Herodotou, 2018a; growth See Schroeder & Kirkorian, 2016) was age dependent.

Kwok et al. (2016) also compared the effect of a touchscreen-based instruction with a face-to-face instruction in learning information about animals among 4- to 8-year-old children. The results revealed a significant improvement in the learning task of both groups; nonetheless, they showed no significant difference between the two groups' rate of learning. By investigating the impact of a touchscreen intervention on science achievement among 3 groups of children, including children, ESL children, and special needs children, Lee and Tu (2016) showed an improvement in the science learning of all three groups. These findings again indicate the affordance of touchscreen technologies for improving the learning condition and outcomes of children with special needs.

4.2.4 Arts

Two of the included studies examined the impact of touchscreens on children's emerging drawing skills. By comparing drawings using a pen with fingertips on touchscreens, Picard et al. (2014) observed the positive effect of pen and paper compared to touchscreen in elementary school participants' art learning. This is likely because it could require more training in finger movements on touchscreens. In a recent study, Kirkorian et al. (2020) examined the efficacy of touchscreens in improving the drawing skills of preschoolers in 3 conditions (i.e., marker on paper, stylus on a touchscreen, finger on a touchscreen tablet). However, unlike Picard et al.'s (2014) findings, they found the positive effect of finger drawing on a tablet compared to the marker and stylus conditions.

4.2.5 Other Learning Areas

The enhancement of children's engagement using touchscreens is also investigated in 5 studies. The engagement evaluation methods employed in these studies included observation logs, a momentary time sampling approach within specific time intervals (e.g., 10 seconds), coding of children's engagement during the videotaped sessions, or calculating the percentages of on-task time during the intervention sessions. For instance, Musti-Rao et al.

(2015) examined how self-mediated iPad instructions could influence the academic engagement of a group of at-risk 6- to 7-year-old children during a period of independent sight word learning. Their results indicated the iPad condition led to higher level of children's engagement compared to the independent print book reading condition. Larabee et al. (2014) also assessed on-task behaviors of three first-grade students during practicing decoding skills using either iPad or standard materials. They observed higher task engagement in the iPad condition. Xu et al. (2021) measured young children's reading engagement based on behavioral, emotional, and verbal dimensions. Touchscreens with hotspots increased children's emotional engagement. This finding is consistent with Willoughby et al.'s (2015) study, resulting in improving children's engagement using alphabet eBooks with letter and object hotspots.

Although several studies used the terms engagement and motivation interchangeably as "motivation is an antecedent to engagement" (Bond et al., 2020, p. 3), one study in the reviewed articles examined the effect of eWriters in children's self-efficacy and motivation towards literacy (Ferdig et al., 2017). Participants were encouraged to use eWriters in both formal (for 6 weeks) and informal settings (for 3 weeks), resulting in a significant increase in children's motivation and self-efficacy in writing. Children's executive functioning was also examined in one of the reviewed studies. Huber et al. (2018) compared the effect of using different modes of iPads (i.e., playing *vs.* watching) in the executive functioning skills of 96 2- to3-year-old young children. Participants showed higher executive functioning skills when playing and interacting with iPad apps compared to watching a video. Zimmermann et al. (2017) investigated the efficacy of touchscreens in improving imitation skills of very young children aged 2.5-3 years. Their results revealed no effect of touchscreen in young children's performance; however, being tested on touchscreens through a social demonstration resulted in better performance. The use of touchscreens was also reported to create opportunities for eliciting more prosocial behaviors (Ralph, 2018). Digital devices in the children's learning context encouraged their sharing behaviors, which in turn created a safer learning environment for young children.

5. Discussion

The investigation of the study characteristics was indicative of a growing interest in examining the effect of digital devices on young children's learning in the recent years since 85% of the reviewed studies have been carried out in the last 5 years (2015-2020). This can be due to the increasing use of these devices by young children in instructional and non-instructional settings. The analysis of the geographical distribution of the reviewed studies revealed an uneven pattern. For example, while 57% of the studies had been performed in North America, we could not find any study conducted in Africa. This uneven geographical distribution of the studies across the world highlights the need for the implementation of more studies in most of the regions throughout the world, especially remote/isolated areas with lower income levels, to benefit from the potentials of technologies for closing the educational attainment gaps. Further, the analysis of the interventions implemented in the reviewed studies revealed a dearth of longitudinal investigations examining both the short-term and long-term effects of touchscreen devices on young children's learning. A great number of the studies (n = 19) were limited to only one or two interventional sessions, focusing on the immediate rather than the lasting effects of touchscreen technologies.

The learning domains addressed in the reviewed studies included literacy, mathematics, science, arts, and other learning outcomes/skills, such as engagement, attention, motivation, self-efficacy, imitation skills, prosocial behaviors, and executive functioning. The research trend analysis revealed that most of the research attention was given to literacy (n = 24) and mathematics (n = 24) learning, while other subject domains such as science (n = 5) and arts (n = 2) were not sufficiently investigated in relation to touchscreen technologies. Accordingly, these areas require further research.

Therefore, it is recommended to perform more studies addressing the effect of touchscreen devices on different subject domains and learning skills/outcomes, especially science and art among children of different age groups. Moreover, it is required to carry out more longitudinal studies to examine the persistence of the educational effects of these tools on the learning outcomes of children living across different geographical regions. Such studies would facilitate the identification of the different developmental, environmental, and cultural factors accounting for the success or failure of integrating digital technologies into early childhood educational settings.

With respect to the overall findings, most of the studies (n = 34) confirmed the positive effects of touchscreen devices on young children's learning, with only two studies reporting purely negative effects. There were also several studies reporting a mixed set of findings (a combination of neutral, negative, and positive effects), and the majority studies reported a combination of neutral and positive findings. While some studies indicated the high effectiveness of touchscreen-based interventions compared to traditional instructions, other studies indicated their equal effectiveness. These findings reveal the potential of touchscreen devices for improving early childhood learning outcomes if employed appropriately.

The reviewed studies involved the comparison of the effects of touchscreens versus traditional teaching approaches or other digital technologies. There were also some investigations comparing the different modes with touchscreens (e.g., playing *vs.* watching) or a specific touchscreen app with other apps. As the reviewed studies demonstrated, some touchscreen-based apps/interventions were more beneficial for a certain age group or under certain learning conditions/ approaches (e.g., played-based learning and interactive learning).

This underscores the significance of considering the conditions and factors contributing to the achievement of the maximal positive effects using touchscreen devices in early childhood educational settings. The factors/conditions affected children's learning with technology can be classified into these five categories: (1) app features (e.g., multimedia, interactivity) and contents (e.g., developmental appropriateness, difficulty level), (2) applied pedagogical approach (e.g., play-based learning, interactive learning, inquiry-based learning), (3) adult mediation (i.e., working with minimal or maximal adult feedback), (4) instructional grouping (i.e., working in pairs, in small groups, or individually), and (5) child age and previous experience/familiarity with touchscreen devices. The app features were frequently discussed in the reviewed studies. These factors can determine the students' learning experiences and outcomes since they engage/disengage or motivate/demotivate the young app users depending on their quality.

For example, hotspots are among the frequent interactive features and core elements of eBooks, designed to elicit verbal or haptic responses from children. However, as the literature indicated, this feature can act like a double-edged sword since it can improve children's comprehension but distract them from their learning process depending on their age and conditions. Regarding this, several factors need to be considered when choosing an eBook equipped with this feature. To name some of these factors, the applied hotpots should be relevant to the content and story flow so that they support the children's understanding of the story rather than distracting them from the content. Moreover, hotspots should be congruent with the child's developmental stage in order not to result in cognitive overload. Last but not the least, the employed hotspots should be visually attractive to encourage the child to keep up with the story and learning activity. The detailed description of each of the factors accounting for the maximal positive effect of touchscreens on childhood learning goes beyond the scope of this study. However, given the significance of this topic, further systematic reviews are needed to gain a deeper insight into the current evidence in this regard.

6. Limitations

We acknowledge that this study has several limitations. This study reviewed the research published from 2010 to 2020 and written in English. Thus, our findings may not include all research published on the effect of touchscreens on early childhood learning although we conducted a robust search of the studies.

7. Conclusion

Our systematic review provided an up-to-date systematic review of the research endeavors addressing the effect of touchscreen devices on early childhood learning and identified the factors/conditions affecting young children's learning with these technologies. The findings of the current review can inform the teachers, educators, and parents about the potential benefits of touchscreen technologies. The ever increasing relevance and use of technologies, especially touchscreen technologies, in early childhood learning both in formal and informal learning settings call for the implementation of more research in the field. For example, the observation of age-dependent effects also calls for the investigation of the impact of touchscreens on children of exactly similar age. This is especially important for studies addressing early learning since children are at a fast-paced cognitive development stage in their early years (Fischer & Bullock, 1984). Accordingly, an age difference of only one year may create a difference in responding to touchscreen-based learning conditions. Therefore, the further investigation of children based on their specific age group would facilitate the identification of the factors and conditions accounting for the optimal learning outcomes during young children's learning with touchscreens.

8. References

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Chapter 4

4. Meta-analysis

4.1 Introduction

The 21st century witnesses a call for evidence-based education research (Ling Niu, 2021). This call has resulted in the implementation of systematic reviews and meta-analyses by education scholars to present evidence to inform planners and policy makers by synthesizing the results of various studies (Gough et al., 2012). Responding to this call, the present study adopts a systematic review/meta-analysis (SR/MA) approach to find the answers to the research questions. Being placed at the top of the evidence-based pyramid, the SR/MA approach is proposed to provide "the best evidence for getting a definitive answer to a research question" (Gopalakrishnan & Ganeshkumar; 2013, p. 6). This can be due to two main reasons: 1) drawing conclusions based on multiple studies rather than a single study, which facilitates the consideration of an effect/relationship and its consistency across a larger number of subjects with greater diversity and 2) using a rigorous approach for synthesizing the research findings (Rosenthal & DiMatteo, 2001; Shelby & Vaske, 2008). The transparency and systematic approach in meta-analysis allow for resolving inconsistencies among research findings (Lee, 2019). Meta-analysis can also unveil the effects or associations that are undetected in other approaches (Lipsey & Wilson, 2001). Therefore, if well-conducted, this approach can be highly helpful in keeping the educators/teachers/policymakers abreast of the contemporary education-related evidence by giving them a summary of statistics based on a large amount of data.

Regarding this, the present study adopted a meta-analysis approach to provide a statistical summary of the effect of touchscreen technologies on early learning performance. The results of this meta-analysis can be complementary to the findings of the integrated systematic review by covering the quantitative end of the spectrum. The meta-analysis was conducted using the PRISMA 2020 statement which is a replacement for the PRISMA 2009 statement. The PRISMA principles provide a series of evidence-based guidelines for reporting SR/MA studies. The application of these guidelines warrants the transparent, precise, and thorough summarization of the literature and enhances the reporting quality (Moher et al., 2009; Page et al., 2021).

4.2 Database Search

Given the integrated format of the present dissertation, part of the studies that were included in the meta-analysis consisted of the papers that had been reviewed in the integrated systematic review and met the renewed inclusion criteria. In addition, I performed another search with the aim of including the most recent literature and achieving a more comprehensive dataset. To avoid selection bias, in addition to adhering to a rigorous systematic review, I aimed to search for both published and unpublished studies (e.g., dissertations, book chapters, and conference papers), which can bring about a more comprehensive dataset that represents true effects.

For the purpose of finding the relevant studies, I searched different databases to make my search exhaustive. As acknowledged by Gurevitch et al. (2013), "no database is complete and multiple databases will make the search more comprehensive"(p. 40). Regarding this, in order to identify the studies addressing the impact of touchscreen technologies on early learning, I carried out a systematic literature search using several electronic databases, including the ERIC, Web of Science, ProQuest, JSTOR, EBSCOHOST, and Sage Journal On-line, all of which were accessed through the Western University Libraries platform. I also used Google Scholar as another searching platform since it easily provides access to the full text/metadata of scholarly literature.

The databases used in the present study have been listed among the core databases for locating journal articles and other sources for educational topics (University of Melbourne, n.d.). Moreover, the selection of the databases was based on the previous studies (e.g., Crompton & Burke, 2020; Kalati & Kim, 2021; Xie et al., 2018), as well as their comprehensiveness and popularity among the educational researchers. For instance, ERIC has already been the first choice of the researchers addressing the education-related literature since it specifically hosts the studies regarding the education science. Furthermore, the Web of Science, containing 100 million multidisciplinary studies, is reported to be the second largest bibliographic database (Research & Writing Guides, n.d.). This database covers conference papers in addition to the peer-reviewed articles, which made it well suited for this study since the inclusion of conference papers to ensure comprehensiveness was one of the intentions of this study.

The use of a variety of databases both guaranteed the preclusion of missing any relevant study and inclusion of various study formats (e.g., peer-reviewed papers, books chapters, dissertations, and conference papers). Additionally, the reference sections of the included studies were searched manually using the backward reference searching approach to find the additional relevant literature. This kind of comprehensive literature search can act as a potential mechanism for minimizing bias (Cooper et al., 2018; Kugley et al., 2017).

4.3 Searching Strategies

According to Cohen et al. (2018), strategic search for the relevant evidence helps the scholars to efficiently achieve the synthesis purpose based on the available resources and pragmatic restrictions. Drawing on this view and in an attempt to make my search strategic, I performed the searching/screening process in three steps. In the first step, I developed a group of keywords acting as search terms in my search process. To this end, I first started a pilot search using such keywords as 'early learning AND touchscreens OR tablets OR iPads' and 'Young children AND touchscreens OR tablets OR iPads'. After finding some relevant resources, I tried to locate some more keywords based on the already retrieved papers in order to expand the search and ensure the retrieval of all pertaining literature. As a result, I came up with the following keywords: ‘Early learning’, ‘Young children’, ‘Childhood education’, ‘Teaching’, ‘Preschoolers’, and ‘Elementary students’ in different combinations with ‘Touchscreens’, ‘Tablets’, ‘iPads’, ‘Mobile devices’ and ‘Educational apps’.

As the second step, I used all the developed searching terms, along with the Boolean operators, to find the studies relevant to the subject of interest using the aforementioned databases. In the final stage, I performed the screening process by checking each of the retrieved studies against the inclusion and exclusion criteria in order to determine the final set of studies that are going to be subjected to review and analysis.

4.4 Inclusion and Exclusion Criteria

The inclusion/exclusion criteria have remarkable importance for the reliability of the meta-analysis findings since they determine the studies that are going to be entered into a meta-analysis, thereby affecting the final research conclusions (Tabak et al., 1991). The establishment of clear inclusion and exclusion criteria determines the scope of the study and reduces the synthesis biases (Suri, 2019). Moreover, defining the inclusion/exclusion criteria enhances the plausibility of achieving reproducible results. To avoid inconsistencies and reduce the potential of bias, it is required to define study selection criteria both clearly and accurately prior to the screening process (McDonagh et al., 2013).

In the present study, I used the inclusion criteria adopted in the integrated systematic review with some modifications to achieve studies that are well responsive to the research questions. Regarding this, the inclusion criteria for this study were peer-reviewed studies, conference papers, book chapters, or dissertations that: 1) have an experimental/quasi-experimental design, 2) involve children aged 2-8 years, 3) include both the learning and test phases, 4) involve the physical manipulation of touchscreens by children during the interventional learning phase, 5) include a non-touchscreen/comparison group (e.g., pretest and other physical manipulatives or learning methods), 6) use a systematic approach to measure the outcomes, 7) have sufficient quantitative data (e.g., means, standard deviations, and sample size or *t*-test and *F*-test values) for effect size calculation, 8) being published in English language, and 9) being published between 2010 and 2022. On the other hand, the exclusion criteria were: 1) having a descriptive or correlational design, 2) inadequacy of data, 3) investigation of learning-irrelevant outcomes (e.g., learners' perception, sleep quality, or health risks), and 4) non-availability of the full-text version.

The studies with an experimental design were given a high priority because as acknowledged by Gay (1992), this approach is "the only method of research that can truly test hypotheses concerning cause-and-effect relationships. It represents the most valid approach to the solution of educational problems, both practical and theoretical, and to the advancement of education as a science" (p. 298). Herodotou (2018) also indicated the efficacy of experimental studies in addressing the subject under study since they facilitate "the actual interaction of children with specific applications and their comparison to baseline measurements" (p. 2). The reason for the selection of 2010 as the starting point was that it marks the date that iPads, as significant touchscreen technologies, were introduced to the market.

4.5 Screening Process

The initial search in the aforementioned databases yielded a total of 2,770 papers. After the removal of 394 duplicates from the retrieved articles, a total of 2,376 studies were subjected to the initial stage of screening. This stage, which involved the manual scanning of the abstracts, and keywords of the retrieved studies, resulted in the exclusion of qualitative and non-experimental studies, review papers, comments, reports, prefaces, and non-English articles, as well as studies with irrelevant objectives to those of the present study, such as those investigating non-touchscreen technologies (e.g., computers), examining young learners/parents/teachers' perceptions of technology use, or targeting touchscreens as an assessment tool rather than a learning medium. During the abstract screening process, in case of information inadequacy in the abstracts, the method sections of the studies were examined to ensure eligibility. This stage resulted in the elimination of 2,085 studies. Accordingly, a total of 291 studies were subjected to full-text review. However, 8 more studies were removed before starting this stage due to the non-availability of their full-text version. At this stage, each of the retrieved papers (n = 283) was examined against the inclusion/exclusion criteria and removed in case of not meeting one of the inclusion criteria. The full-text screening led to the exclusion of 252 studies due to such reasons as participants' age range (n = 46), learning-irrelevant outcomes (n = 7), and inadequacy of statistical data (n = 170). Therefore, a total of 31 studies were identified to meet the eligibility criteria. In addition, out of the 53 articles included in the integrated systematic review, 26 papers met the meta-analysis inclusion criteria. Therefore, a total of 57 studies were included in the meta-analysis. The backward search of the reference lists of these studies did not result in the identification of any other relevant paper. As a result, the final sample of this meta-analysis consists of 57 studies. Figure 2 illustrates the PRISMA flowchart displaying the literature search and screening process of this study.

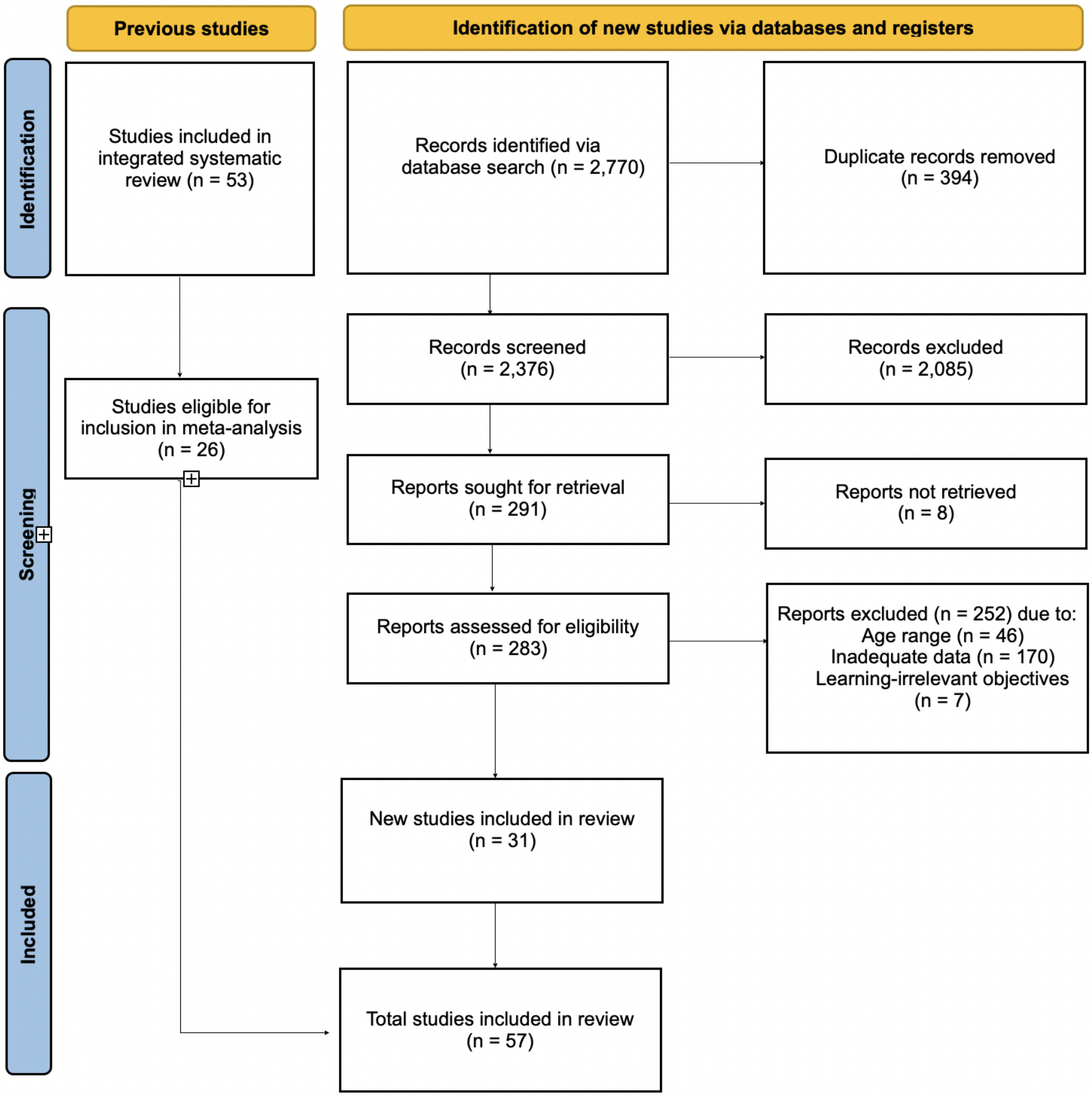

Figure 2: RISMA Flow Chart of Study Selection Process

4.6 Data Extraction and Coding Process

The data extraction phase consisted of three parts of extracting study characteristics (i.e., authors' names, publication year, geographical setting, research design, and sample size), quantitative data for the estimation of effect size, and potential moderators data (i.e., age, learning domain, App type, intervention duration, technology integration level based on SAMR model, adult's feedback, instructional grouping, population, and experimental environment). To facilitate the extraction process, three codebooks, one for the study characteristics data and the other two for the meta-analysis-related data (i.e., quantitative data required for effect size estimation and data related to moderators), were created on Excel sheets to be used as a guide during the data extraction and coding process.

The potential moderators for this study were selected based on the previous studies (e.g., Kim et al. 2021; Sung et al., 2016; Xie et al., 2018), especially the integrated systematic review, which partly targeted the factors affecting young children's learning with touchscreens. In the mentioned study, five factors/conditions, namely app features/contents, applied pedagogical approach, adult mediation, instructional grouping, and child age and previous experience/familiarity with touchscreens, were identified to be effective in learners' outcome. Out of these factors/conditions, app features/contents, adult mediation, instructional grouping, and child age were considered in the meta-analysis as potential moderators. The reason for not considering the applied pedagogical approach and child's experience/familiarity with the touchscreens was that most of the included studies did not clearly provided specific data or explanations about these factors.

In addition to the aforementioned moderators, a set of other moderators were determined based on other relevant literature (e.g., Crompton & Burke, 2020; Xie et al., 2018). As already acknowledged by Xie et al. (2018), it is hard to establish a theoretical framework for the determination of potential moderators of touchscreen's learning effect. Regarding this, the moderator analysis in the present research was established based on an exploratory approach rather than a theoretical one. Therefore, the potential moderators were considered as follows:

1. Child's age: The learners' age was coded based on three age groups of 2-3, 4-6, and 7-8 years. To this end, the participants' mean age was considered for categorizing each study population under each of the three age groups. In case a study had examined age difference when examining touchscreen effect, the data were extracted and entered separately for each of the age groups. For instance, Russo-Johnson et al. (2017) examined the effect of learning with tablets on young children in three age groups of 2, 3, and 4 years old. Accordingly, the data of the mentioned study were entered separately for each of the groups.

2. Learning domain: The learning domain was not limited to just primary outcomes, such as children's domain subject (e.g., math, literacy, and science), rather it was also considered in terms of the secondary outcomes (e.g., learner's engagement and attention). A variety of learning domains had been addressed in the included studies. For the purpose of

analysis, the learning domains were coded into four groups of literacy, mathematics, science, and domain-generic skills. In this categorization, such subject domains as reading, writing, phonemic awareness, beginning sound awareness, alphabet knowledge, vocabulary, and concept of word were coded as literacy (e.g., Amorim et al., 2020, 2022; Zipke et al., 2017). The studies examining number concepts, spatial reasoning, computational skills, or visuo-spatial abilities were coded as mathematics (e.g., Mowafi & Abumuhfouz, 2021). Science included such subject domains as environmental knowledge or factual information about animal life, seasons, and plants (e.g., Kwok et al., 2016; Lee & Tu et al., 2016). Furthermore, the studies addressing problem-solving skills, visual and motor learning skills, engagement, and attention were coded under domain-generic skills (e.g., Tarasuik et al., 2017; Short et al., 2018). In case a study had addressed more than one domain, it was coded for each of the investigated outcomes. For instance, Reeves et al. (2017) investigated the effect of mobile learning on increasing young children's print knowledge, phonological awareness, and math. Therefore, this study was categorized under both literacy (for print knowledge, phonological awareness) and math.

3. Application type: Application type was analyzed as a moderator to figure out if the effect of technology on learning effectiveness varies for the apps classified as educational, entertainment, and edutainment. Accordingly, during the coding process, the studies that used the apps designed especially for achieving educational goals were categorized under educational apps (e.g., Carson, 2020). On the other hand, those performing touchscreen-enhanced interventions based on digital games designed for pure leisure, as well as the social media apps, were coded as entertainment apps (e.g., Antrilli, 2019). Additionally, the studies that used the apps that were intended to be both educational and entertaining were classified as edutainment apps (e.g., Amorim et al., 2022).

4. Intervention duration: The intervention duration was coded based on the total number of minutes the participants were exposed to touchscreens during the intervention phase. This is unlike the previous studies in which the duration was reported either based on the number of sessions or the whole intervention period in week, month, or year. The consideration of the total length of the intervention can yield more accurate results. Based on the minimum (5 min) and maximum (5,760 min) intervention durations that were used in the included studies, this potential moderator was grouped as 5-30, 31-100, 101-300, 301-600, 601-1000, 1001-

2000, and 2001-6000 min. If this amount was variable for different research participants, the mean time of children's learning with touchscreens was considered.

5. Learning setting: Learning setting was taken into account to find out whether the impact of touchscreen technologies on learning performance differs depending on the place in which learning with touchscreens occurs. Regarding this, based on the included studies, the learning setting was coded as regular classroom, empty classroom, home, laboratory, and miscellaneous. In this coding, if the learners were subjected to the touchscreen-based intervention during their regular school hours in their classroom, the setting was categorized as regular classroom (Amorim et al., 2022). In case the learners were taken to a quiet place (e.g., a quiet classroom or playroom) in their own kindergarten/school to receive the touchscreen intervention, the setting was coded as empty classroom (e.g., Carson, 2020). Furthermore, the studies in which the touchscreen-based intervention was performed at learner's home (e.g., Arnold et al., 2021) or in a lab room (Alade et al., 2016) were coded accordingly. In some studies, touchscreen-based learning occurred in more than one setting (e.g., both home and classroom). In such cases, the setting was coded as miscellaneous (e.g., Kowk et al., 2016).

6. Adult's feedback: Both the review of the literature and the findings of the integrated study were indicative of the moderating effect of parents' and teachers' feedback or mediation during children's learning with touchscreens. Therefore, this factor was considered in the moderator analysis to be subjected to statistical examination. To this end, three feedback levels of low, medium, and high were considered for coding the parents' or teachers' feedback during child's learning with touchscreens. In this categorization, if the parents/teachers/interventionists provided no or minor mediation so that the child could work with the device independently, the study was coded as low feedback (e.g., Carson, 2020). Furthermore, in case the parents/teachers/interventionists answered child's questions and gave them prompt to keep them engaged/focused during learning with touchscreens, the study was categorized under medium feedback (e.g., Gecu-Parmaksizhttps & Delialiglu, 2020). Finally, if the adults kept giving focusing, affecting, expanding, encouraging, or regulating feedback during child's learning with the touchscreen, the feedback level was coded as high (e.g., Amorim et al., 2022).

7. Instructional grouping: As reported in the integrated study, the way young children are exposed to learning with touchscreen (i.e., individually or shared) may explain the

variation in child's learning performance. Regarding this, instructional grouping was considered for moderator analysis to find out objective evidence regarding its moderating role in young children's learning with touchscreen technologies. In this study, instructional grouping refers to whether the touchscreen device is used individually by the learner during the educational intervention or if it is shared by one or more peers. Accordingly, to investigate the effect of this potential moderator, it was coded into three levels of one-on-one, pair-group, and small-group.

8. Population type: The study population was coded into two groups of children with special educational needs (SEN) and those without special educational needs (non-SEN). The categorization of population into SEN was based on the definition provided by UNESCO (2011) that states, "a child is commonly recognized as having special educational needs (SEN) if he or she is not able to benefit from the school education made generally available for children of the same age without additional support or adaptations in the content of studies" (para 2). Therefore, SEN can cover a range of needs including physical or mental disabilities, and cognition or educational impairments. According to this definition, the studies performed on young children with any disabilities (e.g., developmental delays, developmental language disorders, and autism) or those with educational impairments (e.g., at-risk learners with difficulty learning a subject domain) were grouped as SEN (e.g., Carson, 2020; D'Agostino et al., 2016; Soares et al., 2020), while the studies carried out on children without such difficulties or problems were categorized as non-SEN (Short et al., 2018; Wu, 2020).

9. Technology integration level: The degree of technology integration was investigated based on the four levels of SAMR model, namely substitution, augmentation, modification, and redefinition. The expanded definition of SAMR levels provided by Crompton & Burke (2020) was employed to map each touchscreen-based intervention into each of the SAMR levels. The included studies benefited from the affordances of touchscreens across various levels. One thing that should be noted is that in the reviewed studies, the touchscreen-based activities were dependent on the apps used during the educational intervention. Therefore, the categorization of the touchscreen-based activities was carried out based on the apps used in the studies.

4.7 Data Analysis

4.7.1 Effect Size Calculation

The analysis of data was performed in two stages, one of which involved the descriptive statistics of the included studies and the other one targeted the meta-analysis process. The meta-analysis was performed using the Comprehensive Meta-Analysis (CMA) package program, version 3. For the purpose of the calculation of the effect size, the mean, standard deviation, sample size, *p*-value, *t* value, and *F* value reported in the studies were used based on the multiple functions of the CMA program.

For the studies with multiple outcomes, as suggest by Borenstein et al. (2021), we computed composite effects with the variance using an excel sheet provided by the developers of the CMA program. This calculation was performed in a separate excel sheet because the CMA program treats the effect sizes for multiple outcomes as completely independent by assuming the correlation among outcomes as 0, which over-estimates the precision of the summary effect (since the correlation is probably higher than 0). The spreadsheet allows for computing composite effects with a variance based on any correlation. The correlation used for multiple outcomes were based on the literature. For instance, for a study by Messer et al. (2017) addressing the effect of touchscreens on both literacy and math, the math and literacy correlation was taken as 0.30 based on a study performed by Džumhur et al. (2022) reporting a correlation range of 0.19-0.30 among math and literacy components in preschoolers. As suggested by the CMA developers, if we expect that the correlation falls within the range of 0.60 to 0.80, we may elect to use 0.80 (yielding the highest estimate of the variance). After the calculation of the composite effects in the excel spreadsheet, they were entered back into CMA. This method, which is referred to as 'composite approach', precludes overestimation which can be caused by the dependence of multiple effect sizes on the same participants (Borenstein et al., 2021). The interpretation of the effect size magnitude was based on the benchmarks suggested by Cohen (1988). In this categorization, an effect size of around 0.20 is interpreted as small, while the effect sizes of about 0.50 and 0.80 are respectively considered medium and large.

4.7.2 Homogeneity Test

The investigation of the presence of heterogeneity was carried out using the Cochran's *Q* test, which is a traditional statistical test for checking the hypothesis of effect size homogeneity

(Sedgwick, 2012). However, given the inability of this test to demonstrate the magnitude of the heterogeneity, I^2 was also calculated as a common index of the degree of heterogeneity (Higgins & Thompson, 2002). As proposed by Higgins et al. (2003), I^2 values of around 25%, 50%, and 75% are representative of the presence of low, medium, and high heterogeneity, respectively (Higgins et al., 2003).

4.7.3 Publication Bias Test

Publication bias occurs as a result of the non-publication of the studies with insignificant results, which impacts the accurate synthesis of the evidence in a given domain (Song et al, 2013). Publication bias in meta-analysis can threaten the validity and generalization of the findings (Lin & Chu, 2017). Various methods have been proposed to avoid the incidence of publication bias. These include implementing a comprehensive search throughout all probable sources, including both published and unpublished research, such as conference papers and PhD theses, and not limiting the search to the outcomes (Song et al., 2013). As previously mentioned, in this study, in an attempt to eliminate publication bias, I performed a comprehensive search in different databases and included both published and unpublished studies.

The use of statistical methods is another approach to ensure that the sample of included studies is not affected by publication bias. In the present research, publication bias was tested using the funnel plot test and Egger's regression test, as one of the bias indicators of funnel scatter plots (Egger & Smith, 1997). Additionally, the fail-safe *N* method (Rosenthal, 1979) was employed as another estimation of publication bias to identify the number of additional negative-outcome studies required in a meta-analysis to make the results insignificant.

Chapter 5

5. Meta-analysis Results

5.1 Overall Analysis

A total of 57 studies (including 59 effect sizes) were included in the present meta-analysis. This section initially presents the characteristics of the included studies in relation to their publication features and learning domains. Then, it continues with presenting the results of the meta-analysis/systematic review based on the research questions.

5.1.1 Descriptive Analysis of the Included Studies

Figure 3 depicts the distribution of the included studies based on their publication year. As illustrated in this figure, there has been a growing trend in the studies exploring the impact of touchscreens on early learning over the second half of the last decade, with 86% of the studies having been conducted within 2016-2022. Although the number of the performed studies was lower in 2021 (n = 4) and 2022 (n = 1) in comparison to the former years, this can be due to the restrictions caused by COVID-19, which made the implementation of experimental studies highly difficult if not impossible. The investigation of the included studies based on their geographical distribution also revealed almost the same findings as those of the integrated systematic review, with North America (51%) having the highest share of research addressing the effect of touchscreens on early learning and Africa (5.2%) and South America (3.5%) having the lowest rates (Figure 4). Regarding the sources of the included studies, peer-reviewed articles with a rate of 80.7% constituted a remarkable proportion of the included studies while the reviewed dissertations and book chapters had the rates of 12.3% and 7%, respectively (Figure 5).

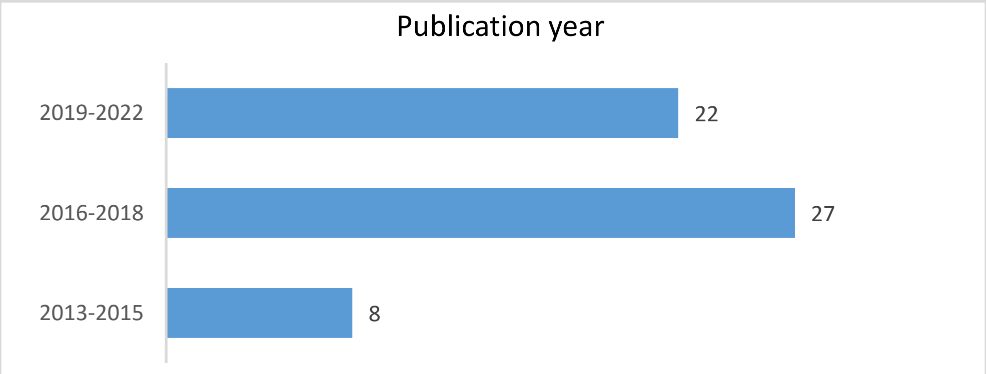

Figure 3: Distribution of Included Studies Based on their Publication Year

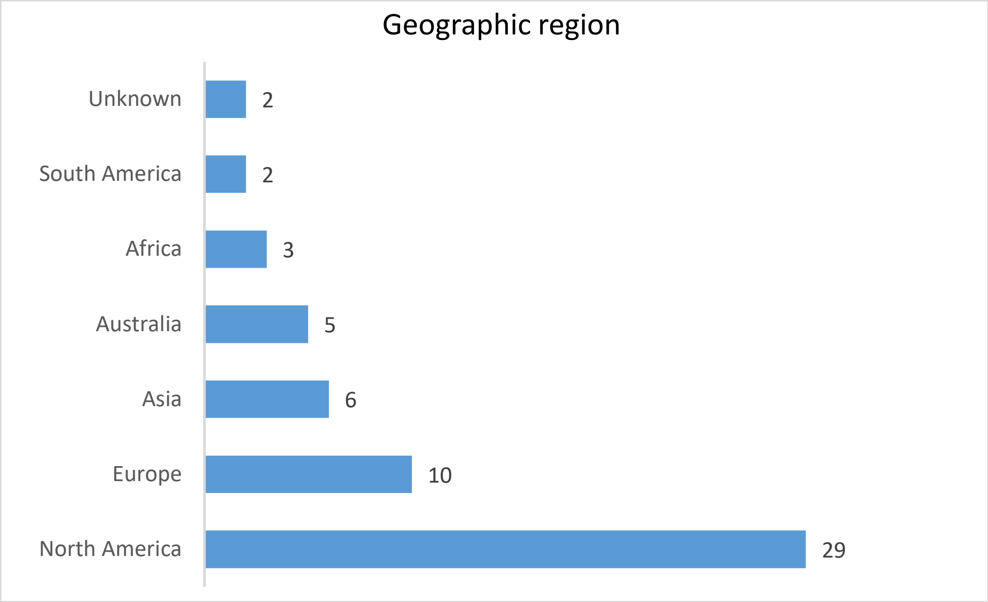

Figure 4: Distribution of Included Studies Based on their Geographic Region

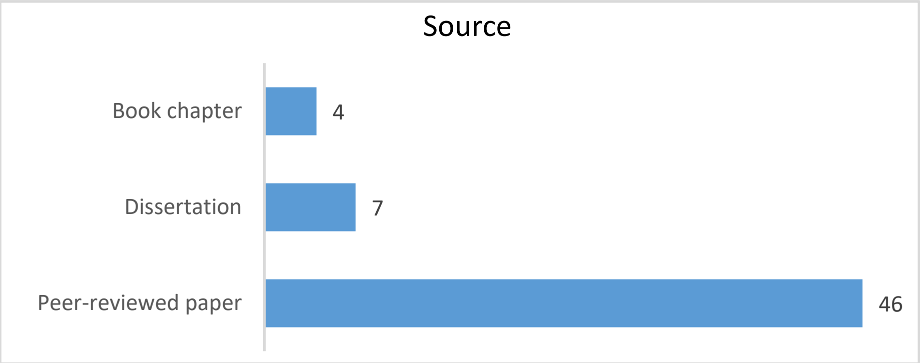

Figure 5: Distribution of Included Studies Based on their Sources

As stated previously, early learning in the present study was not limited to only primary outcomes, such as subject domains like literacy or mathematics, rather it also targeted secondary learning outcomes, such as motivation, collaboration, and attention, which were categorized under domain-generic skills for the sake of analysis. Figure 6 displays the distribution of the included studies based on the investigated learning outcomes. Among the studies reviewed and analyzed in the current research, mathematics studies (44.5%), followed by literacy research (38%), had the highest frequency. Comparatively, science (6.5%) had a much lower frequency in relation to the other two primary subject domains (i.e., literary and mathematics). Regarding the secondary outcomes, 11% of the studies had examined the effect of touchscreens on young children's domain-generic skills.

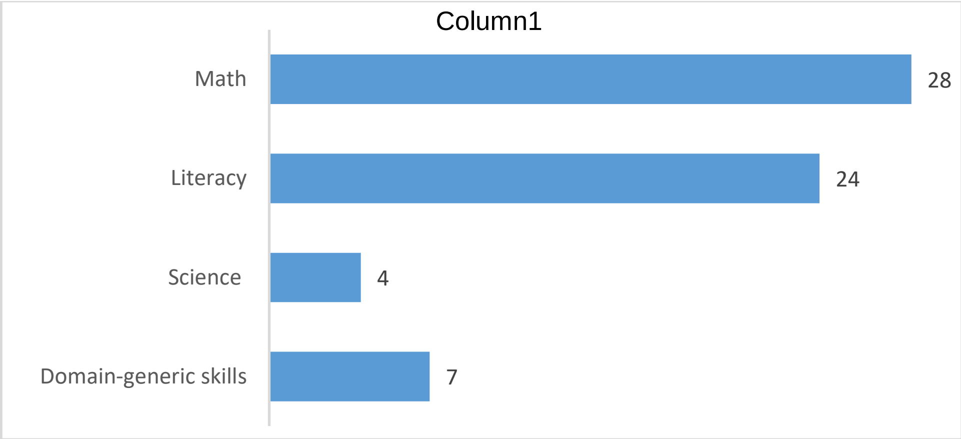

Figure 6: Distribution of Included Studies Based on the Investigated Learning Outcomes

5.1.2 Pooled Effect Size

Out of the 57 studies included in the present meta-analysis, a total of 59 effects sizes were calculated. These studies included a total of 6,857 participants with a mean age ranging from 27.03 to 97 months. Figure 5 illustrates the forest plot presenting the point estimate of each effect size with a 95% confidence interval. In this analysis, an effect size below zero represents the negative effect of touchscreens on early learning, while an effect size above zero indicates the positive learning effect of these devices.

5.1.3 Homogeneity Analysis

The results of the Cochran's Q test demonstrated a statistically significant level for the Q statistic ($Q = 337.21$, $p = 0.00$), thereby rejecting the null hypothesis of homogeneity. Additionally, based on the classifications proposed by Higgins et al. (2003), the I^2 estimate ($I^2 = 82.8$) was suggestive of high heterogeneity (I^2>%75). These results supported the assumption of random-effects model; therefore, the pooled effect of touchscreens on early learning performance was investigated using the random-effects model. The random-effects model takes into account the heterogeneity among studies (Freemantle & Geddes, 1998). This heterogeneity also indicates the presence of differences in effect sizes due to factors other than the subject-level sampling error; therefore, it justifies the implementation of moderator analysis to identify the source of heterogeneity.

Study name	Subgroup within study	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Pungali (2017)	Math	-0.895	0.130	0.017	-1.151	-0.639	-6.864	0.000
Krcmar & Cingel (2014)	Literacy	-0.441	0.127	0.016	-0.690	-0.192	-3.475	0.001
Soares et al. (2020)	Literacy	-0.330	0.381	0.145	-1.076	0.416	-0.867	0.386
Kowk et al. (2016)	Science	-0.196	0.216	0.047	-0.619	0.228	-0.905	0.366
Esteraich (2018)	Generic skills	-0.049	0.089	0.008	-0.224	0.126	-0.548	0.584
Messer et al. (2018)	Generic skills	0.030	0.408	0.167	-0.771	0.830	0.073	0.942
Short et al. (2018)	Generic skills	0.054	0.306	0.094	-0.546	0.653	0.176	0.860
Matoon et al. (2015)	Math	0.077	0.408	0.167	-0.723	0.878	0.190	0.850
Esteraich (2018) (low feedback)	Generic skills	0.119	0.126	0.016	-0.129	0.367	0.941	0.347
Ronimus et al. (2020)	Generic skills	0.130	0.259	0.067	-0.377	0.637	0.503	0.615
Teepe et al. (2017)	Literacy	0.136	0.176	0.031	-0.209	0.481	0.772	0.440
Willoughby et al. (2015)	Literacy	0.141	0.232	0.054	-0.314	0.596	0.607	0.544
Cornue et al. (2019)	Math	0.147	0.239	0.057	-0.321	0.615	0.616	0.538
Miller (2018)	Math	0.148	0.557	0.310	-0.944	1.240	0.266	0.790
Outhwaite et al. (2019)	Math	0.149	0.447	0.200	-0.728	1.026	0.333	0.739
Allison (2016)	Literacy	0.152	0.138	0.019	-0.118	0.422	1.103	0.270
Messer et al. (2018)	Math	0.160	0.187	0.035	-0.207	0.527	0.855	0.392
Amorim et al. (2020)	Literacy	0.180	0.114	0.013	-0.043	0.403	1.579	0.114
Ronimus et al. (2020)	Literacy	0.225	0.259	0.067	-0.283	0.733	0.869	0.385
Lee & Tu	Science	0.262	0.080	0.006	0.105	0.419	3.265	0.001
Walter-laager et al. (2017)	Literacy	0.272	0.350	0.122	-0.414	0.958	0.778	0.437
Walton2018)	Math	0.315	0.221	0.049	-0.119	0.749	1.423	0.155
Antrilli (2019)	Math	0.316	0.232	0.054	-0.139	0.771	1.360	0.174
Amorim et al. (2022)	Literacy	0.323	0.195	0.038	-0.059	0.705	1.657	0.098
Cary et al. (2020)	Math	0.367	0.095	0.009	0.181	0.553	3.869	0.000
Pitchford et al. (2019)	Math	0.387	0.128	0.016	0.137	0.638	3.029	0.002
Blackwell (2015) Exp.2	Literacy	0.390	0.128	0.016	0.140	0.640	3.057	0.002
Pitchford et al. (2019)	Literacy	0.393	0.113	0.013	0.172	0.614	3.482	0.000
Zipke (2017) Exp.1	Literacy	0.397	0.100	0.010	0.201	0.593	3.970	0.000
O'Toole & Kannass	Literacy	0.413	0.202	0.041	0.016	0.810	2.040	0.041
Spencer (2013)	Math	0.432	0.164	0.027	0.110	0.754	2.629	0.009
Mowafi & Abumufouz (2021)	Math	0.442	0.456	0.208	-0.452	1.336	0.969	0.332
Oakley et al. (2020)	Literacy	0.467	0.092	0.008	0.286	0.647	5.071	0.000
Lee & Choi (2020)	Math	0.482	0.292	0.085	-0.089	1.053	1.653	0.098
Masataka (2014)	Literacy	0.499	0.371	0.137	-0.228	1.226	1.346	0.178
Papakadis et al (2016)	Math	0.551	0.127	0.016	0.301	0.801	4.325	0.000
Schacter et al. (2016)	Math	0.570	0.204	0.042	0.170	0.970	2.794	0.005
Neuman (2018)	Literacy	0.630	0.428	0.183	-0.208	1.468	1.473	0.141
Patchan & Puranik (2016)	Literacy	0.630	0.362	0.131	-0.080	1.340	1.739	0.082
Papadakis et al. (2018)	Math	0.670	0.135	0.018	0.404	0.935	4.945	0.000
Disney et al. (2019)	Math	0.681	0.249	0.062	0.193	1.169	2.735	0.006
Alade et al. (2016)	Math	0.713	0.326	0.106	0.074	1.352	2.186	0.029
Arnold et al. (2021)	Literacy	0.717	0.295	0.087	0.139	1.295	2.432	0.015
Wu & Kim (2019)	Generic skills	0.814	0.780	0.608	-0.714	2.342	1.044	0.297
Schenke et al. (2020)	Math	0.828	0.257	0.066	0.325	1.331	3.228	0.001
Wang et al. (2016)	Math	0.836	0.314	0.099	0.220	1.452	2.660	0.008
D'Agostino et al. (2016)	Literacy	0.837	0.395	0.156	0.063	1.611	2.119	0.034
Russo-Johnson et al. (2017) (4years)	Literacy	0.840	0.291	0.085	0.270	1.410	2.887	0.004
Reeves et al. (2017)	Literacy	0.875	0.420	0.176	0.052	1.698	2.084	0.037
Russo-Johnson et al. (2017) (2-3years)	Literacy	0.910	0.249	0.062	0.422	1.398	3.656	0.000
Schacter & Jo (2017)	Math	0.940	0.103	0.011	0.738	1.142	9.110	0.000
McKenna (2012)	Math	0.967	0.486	0.236	0.015	1.919	1.991	0.047
Corcoran (2018)	Literacy	1.044	0.282	0.080	0.490	1.597	3.697	0.000
Schacter & Jo (2016)	Math	1.090	0.194	0.038	0.710	1.470	5.627	0.000
Wang et al. (2021) Exp.2	Math	1.118	0.336	0.113	0.460	1.777	3.329	0.001
Schroeder & Kirkorian (2016)	Science	1.144	0.402	0.162	0.355	1.933	2.842	0.004
Wu (2020)	Math	1.189	0.290	0.084	0.621	1.757	4.101	0.000
Pila et al. (2019)	Science	1.344	0.332	0.110	0.694	1.994	4.052	0.000
Pitchford (2015)	Math	1.363	0.525	0.276	0.333	2.393	2.594	0.009
Carson (2020)	Literacy	1.368	0.679	0.461	0.037	2.699	2.015	0.044
Reeves et al. (2017)	Math	1.385	0.437	0.191	0.529	2.241	3.170	0.002
Durgungoz & Durgungoz (2021)	Generic skills	1.917	0.623	0.388	0.696	3.138	3.078	0.002
Gecu-Parmaksiz & Delialioglu (2020)	Math	1.940	0.286	0.082	1.380	2.500	6.787	0.000
		0.473	0.060	0.004	0.356	0.589	7.936	0.000

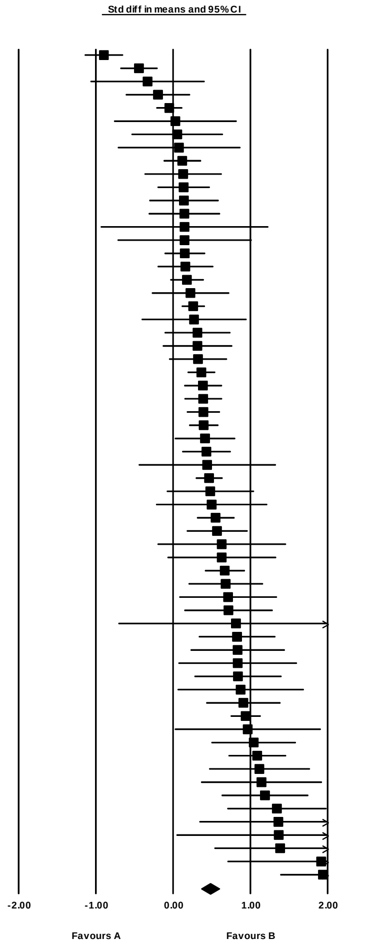

Figure 7: Forest Plot of Individual Effect Sizes

5.1.4 Publication Bias Analysis

Figure 8 illustrates the funnel plot of the effect sizes of the included studies. As can be seen, the scale is scattered between -2 and 2 because the effect size of one of the studies is around 2, and the standard error is between 0 and 0.8. Considering the scattered version of the graphic and lack of any remarkable asymmetry, it can be interpreted that the publication choice was not biased. However, the results of the Egger's test were indicative of the likelihood of the effect of publication bias on the findings of the current meta-analysis (intercept = 1.56, $p<0.5$). Nonetheless, the results of the classic fail-safe *N* test demonstrated that a total of 3,833 studies with non-significant findings would be required to nullify the cumulative effect size obtained in this meta-analysis (Table 1). According to Rosenthal (1979), if the fail-safe *N* is larger than (5) *k* + 10 (where *k* is the number of effect sizes), then the fail-safe *N* is considered large enough to signify the robustness of the result and reject the presence of publication bias. In the present study, the fail-safe *N* was achieved at 3,833; therefore, based on 5(59) + 10 = 305 since the fail-safe *N* is much bigger than this number (i.e., 3,833>305), it can be concluded that the estimated effect size of unpublished studies is unlikely to affect the effect size of the present meta-analysis.

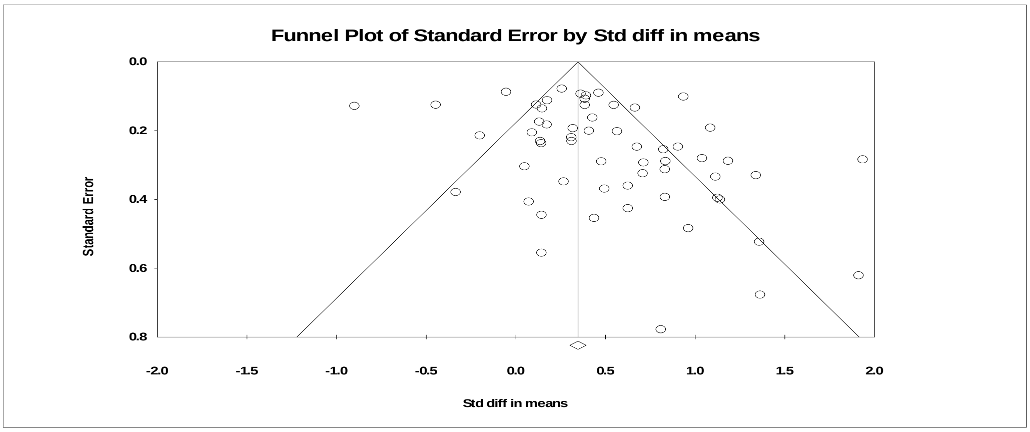

Figure 8: Funnel Plot of the Studies Investigating the Effect of Touchscreens on Early Learning

Table 1: Results of the Classic Fail-Safe *N*

Z-value for observed studies	15.91
P-value for observed studies	0.00
Alpha	0.05
Tails	2
Z for alpha	1.95
Number of observed studies	59
Number of missing studies that would bring the p-value to >alpha	3,833

5.2 Meta-analysis Research Question 1

The first research question addressed the overall effect of touchscreens on young children's learning. As demonstrated in Table 2, the results of the meta-analysis revealed a random weighted average effect size of 0.48 with a %95 confidence interval of 0.35-0.60, which suggests that the mean effect size in the universe of comparable studies could fall anywhere within this interval. As per Cohen's (1988) classification, the obtained effect size (d = 0.48) is representative of a medium effect size. Regarding this, it can be concluded that learning with touchscreens can result in better learning performance in young children in comparison to learning in the absence of touchscreens. This result is similar to those obtained by Xie et al. who also reported a medium effect size for the effect of touchscreens on early learning performance.

Table 2: Pooled Effect of Using Touchscreens on Early Learning

Dependent variable	Effect size					Homogeneity test		
	k	Cohen's *d*	*p*	95% CI	*Z*	*Q*	*P*	I^2
Early learning	59	0.48	0.00	[0.35-0.6]	7.67	337.21	0.00	82.80

5.3 Meta-analysis Research Question 2

The second research question targeted the presence of factors/conditions moderating the effect of early learning with touchscreens. To find the answer to this question, a moderator analysis was run. Moderator analysis facilitates the examination of the effect of a third variable on the relationship between two variables. This type of analysis allows for testing when or under what conditions an effect takes place (Williams, 2012).

5.3.1 Moderator Analysis

Table 3 demonstrates the results of the moderator analyses based on the nine potential moderators investigated. Since the potential moderators were all categorical variables, they were subjected to subgroup analyses.

Regarding the learning domain, this variable was investigated across four levels, namely mathematics, literacy, science, and domain-generic skills. As seen in Table 2, the results demonstrated a statistically significant moderating effect for the learning domain (Q = 22.81, p = 0.00). In this analysis, mathematics (d = 0.56, p = 0.00) and science (d = 0.55, p = 0.05) had almost equal and the largest effect sizes among other learning outcomes. This suggested that young children benefited more from touchscreens when learning mathematics and science, compared to other domains. In addition, the use of touchscreens for learning literacy was found to have a Cohen's d of 0.37 (p = 0.001), which is representative of an almost medium effect size. However, in this categorization, domain-generic skills showed a very low and statistically non-significant effect size (d = 0.02, p = 0.71).

Considering child's age, the moderator analysis demonstrated no significant moderating effects for this variable (Q = 2.33, p =0.31). Based on the analysis, the older children (i.e., 4-5 and 6-7 years old) had a higher effect size for learning with touchscreens (d = 0.50, p = 0.00 and d = 0.43, p = 0.00 respectively), compared to the younger age group (i.e., 2- to 3-year-olds; d = 0.30, p = 0.00).

With regard to the application type, although no significant variation was detected across the levels of this category (Q = 4.65, p = 0.09), remarkably, young children benefited more from learning with the touchscreens when using edutainment applications (d = 0.50, p = 0.00), compared to the educational applications (d = 0.31, p = 0.002). Nonetheless, the effect sizes for the entertainment applications was insignificant and small (d = 0.20, p = 0.15).

The length of exposure to touchscreen-based interventions was also found not to significantly affect the influence of touchscreens on young children' learning (Q = 1.57, p = 0.97). However, in this categorization, except for the intervention duration of 601-1000 min (d = 0.32, p = 0.06), the other five levels demonstrated both statistically significant and moderate effect sizes (d = 0.41-0.60, p < 0.01). Among these levels, 101-300 min of exposure was found to have the highest effect size (g = 0.60, p = 0.00). On the other hand, the lowest effect size was recorded for the intervention duration of 5-30 min (d = 0.41, p = 0.00).

The investigation of the moderating effect of technology integration level based on the SAMR framework was performed using the first three levels of this model, namely substitution, augmentation, and modification, since there was no study using touchscreens at the redefinition level. The data were indicative of the moderating effect of touchscreen integration level on young children's learning ($Q = 6.01$, $p = 0.04$). As the subgroup analysis demonstrated, only the enhancement levels of SAMR showed statistically significant results, with the augmentation level having the highest effect size ($d = 0.54$, $p = 0.01$). Regarding the transformational levels of SAMR, the data were indicative of a very small effect size ($d = 0.005$, $p = 0.98$), which was not statistically significant.

The amount of adult's feedback during learning with touchscreens was also found to affect the influence of these devices on young children' learning. In this categorization, the low and medium feedback levels showed a moderate effect size ($d = 0.53$, $p = 0.00$ and $d = 0.61$, $p = 0.00$, respectively), while a high feedback level demonstrated a small effect size ($d = 0.18$, $p = 0.00$). This can indicate that the provision of low to moderate feedback level during young children's learning with touchscreens can lead to better learning outcomes.

Instructional grouping was another variable the moderating effect of which was investigated in the present research. The results indicated no significant results for this category ($Q = 3.94$, $p = 0.13$). Nonetheless, the use of touchscreens on a one-on-one basis was found to result in higher learning effectiveness ($d = 0.54$, $p = 0.00$) than the shared use of these devices ($d = 0.35$, $p = 0.00$ and $d = 0.31$, $p = 0.00$ for in-pair and small-group categories, respectively).

The investigation of learner type based on the two groups of learners with and without special educational needs also demonstrated no statistically significant difference in the mean effect size across the two levels of this variable. However, the subgroup analysis at each of the levels demonstrated a statistically significant effect size only for the non-SEN group ($d = 0.48$, $p = 0.00$).

Finally, the experimental environment was examined considering both formal and informal settings at the five levels of regular classroom, empty classroom, lab, home, and miscellaneous. The sub-group analysis showed no statistically significant results for this variable ($Q = 4.89$, $p = 0.29$). This signifies that young children's learning outcome does not differ depending on the place in which they are learning with touchscreens. Out of the five places investigated, only regular and empty classroom showed statistically significant effect sizes ($d = 0.45$, $p = 0.00$ and $d = 0.62$, $p = 0.00$, respectively).

Table 3: **Moderator Analyses of Early Learning with Touchscreens**

Moderators	*K*	Cohen's *d*	Standard Error	95% Lower	95% Upper	*Z*	2-sided *p*-value	*Q*(*df*)	*p*-value
Learning domain								22.81(3)	0.00
Mathematics	26	0.56	0.11	0.34	0.78	5.04	0.00		
Literacy	23	0.37	0.07	0.22	0.51	5.00	0.00		
Science	6	0.55	0.29	-0.01	1.23	1.91	0.05		
Domain-generic skills	4	0.02	0.06	-0.10	0.15	0.36	0.71		
Age								2.33(2)	0.31
2-3 years	6	0.30	0.09	0.11	0.50	3.09	0.00		
4-6 years	48	0.50	0.07	0.34	0.65	6.44	0.00		
7-8 years	8	0.43	0.12	0.18	0.67	3.46	0.00		
App type								4.65(2)	0.09
Educational	17	0.31	0.09	0.11	0.50	3.15	0.00		
Entertainment	2	0.20	0.14	-0.07	0.47	1.43	0.15		
Edutainment	40	0.50	0.07	0.35	0.66	6.47	0.00		

Length of intervention								1.57(6)	0.95
5-30 min	13	0.41	0.15	0.11	0.70	2.74	0.00		
31-100 min	5	0.46	0.14	0.19	0.73	3.35	0.00		
101-300 min	13	0.60	0.16	0.29	0.90	3.78	0.00		
301-600 min	10	0.45	0.10	0.25	0.65	4.40	0.00		
601-1000 min	11	0.32	0.17	-0.02	0.66	1.84	0.06		
1001-2000 min	4	0.43	0.13	0.15	0.70	3.09	0.00		
2001-6000 min	3	0.42	0.10	0.22	0.63	4.10	0.00		
Technology integration								6.01(2)	0.04
Substitution	14	0.28	0.11	0.01	0.50	2.47	0.01		
Augmentation	41	0.54	0.06	0.00	0.67	8.52	0.00		
Modification	4	0.00	0.34	0.11	0.68	0.01	0.98		
Adult's feedback								16.50(2)	0.00
Low	23	0.53	0.10	0.33	0.72	5.27	0.00		
Medium	13	0.61	0.10	0.40	0.82	5.67	0.00		
High	12	0.18	0.62	0.06	0.30	2.94	0.00		
Instructional grouping								3.94(2)	0.13
One-on-one	46	0.54	0.08	0.37	0.70	6.57	0.00		
Pair group	9	0.35	0.07	0.20	0.49	4.77	0.00		
Small group	3	0.31	0.10	0.10	0.52	2.91	0.00		
Type of learners								0.01(1)	0.91
SEN	6	0.45	0.26	0.07	-0.01	1.03	0.05		

non-SEN	56	0.48	0.06	0.00	0.35	0.60	0.00		
Experimental setting								4.89(4)	0.29
Regular classroom	34	0.45	0.07	0.30	0.60	5.95	0.00		
Empty classroom	11	0.63	0.17	0.29	0.97	3.65	0.00		
Lab	2	0.44	0.31	-0.17	1.05	1.40	0.15		
Home	3	0.15	0.15	-0.15	0.45	0.98	0.32		
Miscellaneous	9	0.33	0.18	-0.01	0.69	1.86	0.06		

5.4 Research Question 3

The third research question targeted the status of touchscreen technology integration for early childhood education by addressing the SAMR levels with which the young learners are engaged when using touchscreens for educational purposes. In addition, this question included a sub-question aimed at detecting the trend regarding the touchscreen integration levels based on the SAMR model in different subject areas. To respond to these questions, as recommended by Miles et al. (2018), the counting method was used given its appropriateness for aggregating data and identifying the trends in a set of data.

The examination of the touchscreen-based learning activities used in the reviewed studies demonstrated that touchscreens were integrated into early childhood educational settings at only three levels of the SAMR framework, including substitution, augmentation, and modification, with no case of using touchscreen-based activities at the redefinition level.

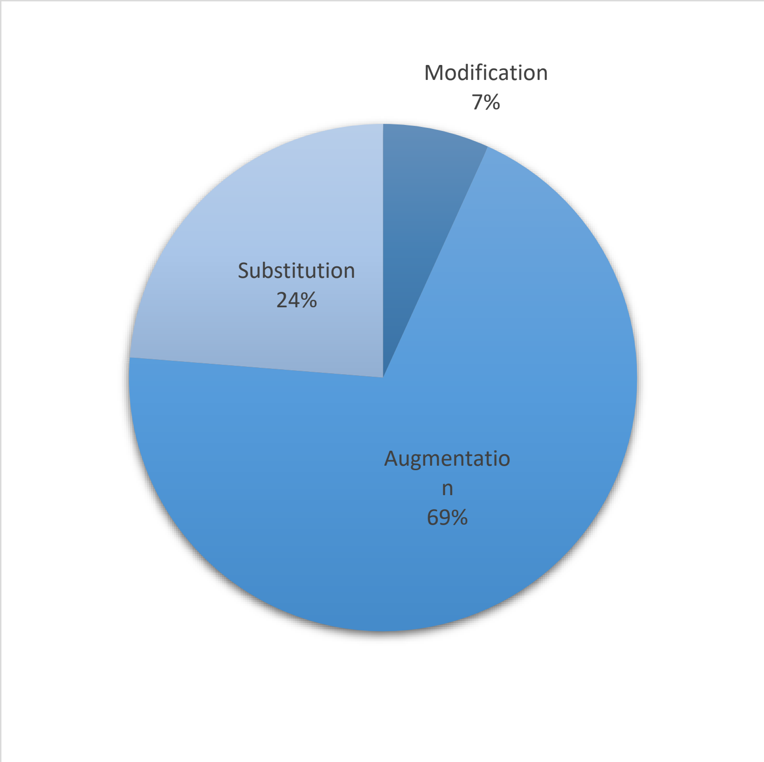

Figure 7: SAMR Levels Distribution Across the Included Studies

Figure 7 displays the distribution of SAMR levels across the reviewed studies. Regarding the substitution level, the data demonstrated that in 24% of the studies, touchscreens were used as a direct tool substitute to the traditional teaching/learning approaches/materials, without any functional changes. For instance, Krcmar & Cingel (2016) compared the effect of tablet-based and traditional paper book formats on children's comprehension. In the mentioned study, the researchers attempted to keep the electronic and traditional paper book the same by not using the tablet affordances (e.g., sound and interactive features). Accordingly, there was no difference between the two media unless the format since (i.e., electronic vs. paper form) the learners were essentially doing the exact same things they used to do in their classroom prior to the integration of tablets into their educational setting.

The augmentation level was found to be the most commonly used level in the examined studies for integrating touchscreen-based interventions into early childhood educational settings. In this regard, young children were engaged with touchscreens at the augmentation level of the SAMR model in 69% of the studies. At the augmentation level, technology is likely to improve the learners' learning experience by offering new potentials. According to Puentedura (2012), in this level, the process of performing the task is not exactly similar to the way it is performed in the absence of technologies. It is argued that when technology is integrated at the augmentation level, it offers greater opportunities for learners' engagement by enhancing learning experience and making it more efficient. . For instance, in a study, Arnold et. al. (2021) used a touchscreen app consisting of a sequence of lessons targeting emergent literacy which exposed the children to a set of tasks that were supposed to be completed to progress to the subsequent level. By providing feedback and allowing for adjusting activities based on children's responses, the app facilitated personalized learning. Therefore, in this case, the technology was not integrated as only a substitute but enhanced learning by providing new potentials and opportunities for the learners.

The analysis of the studies at the transformational levels of the SAMR framework revealed only a few studies targeting these levels. While only 7% of the studies integrated touchscreens at the modification level, there was no research having young children engaged with this technology at the redefinition level. At the modification level, the learners are subjected to activities that cannot be accomplished without the presence of technology. By allowing for creating products (i.e., learning artifacts) or engaging in a different learning process, this level of technology integration transforms the learning process for the students. For example, in a study performed by Oakley et al. (2020), as part of the touchscreen-based intervention, the students were engaged in a multisensory learning experience in which the digital technology was used to transcribe children's oral stories for creating a digital story using animations, images, and sounds created by children with the aid of touchscreens. This learning experience provided the children with a transformational learning opportunity by engaging them in a constructive and meaningful learning process that went beyond simply acquisition of knowledge and encouraged the children to consciously get involved in making meaning of their lives.

However, redefinition, as the highest level of SAMR model and representative of the transformational level of technology integration was not observed in any of the included studies. According to Puentedura (2018), the integration of technology at the redefinition level supports the stimulation of deeper analytical thinking, thereby improving learning outcomes in a remarkable manner. Using the instance used for the modification level, if in the mentioned study, the students were given a chance to publish their created digital stories online where it could be viewed and commented by peers and the broader community and be used as a resource for others to learn from, they benefited from technology integration at the redefinition level. Accordingly, this level exposes students to new exploration and growth opportunities that they could not have experienced without technologies. Puentedura (2018) also posits that the use of technology at this level supports learners to take charge of their own learning/education by giving them a sense of autonomy and ownership.

Based on the obtained results, it can be stated that technology integration into early childhood education settings is mostly operating at the enhancement level rather than the transformational level. In other words, in the context of early learning, touchscreen technologies are mostly used for enhancing learning for young learners, rather than transforming it.

To respond to the sub-question of research question 3, touchscreen integration was investigated based on the SAMR across each of the investigated subject domains, namely mathematics, literacy, science, and domain-generic skills. Figure 8 depicts the SAMR level-based distribution of touchscreen interventions across various learning domains in early childhood studies. Considering mathematics, in the majority of the studies, touchscreens were used at the augmentation level (80.8%). However, only 15.4% of the studies integrated touchscreens for mathematics learning just as a substitute for the traditional teaching approaches/materials. The modification level of technology integration was also observed in only 3.8% of the studies targeting mathematics learning in early years. With regard to the studies using touchscreens for literacy learning, the substitution (39%) and augmentation (48%) levels had a close proportion, while modification level was performed in only 13% of the studies. The investigation of the studies focusing on science learning/teaching with the aid of touchscreens in the context of early childhood education demonstrated that 75% of the studies using touchscreens for early science learning integrated these devices at the augmentation level, while %25 of the studies used touchscreens at the substitution level. However, there was no study integrating touchscreens for science learning at the modification level.

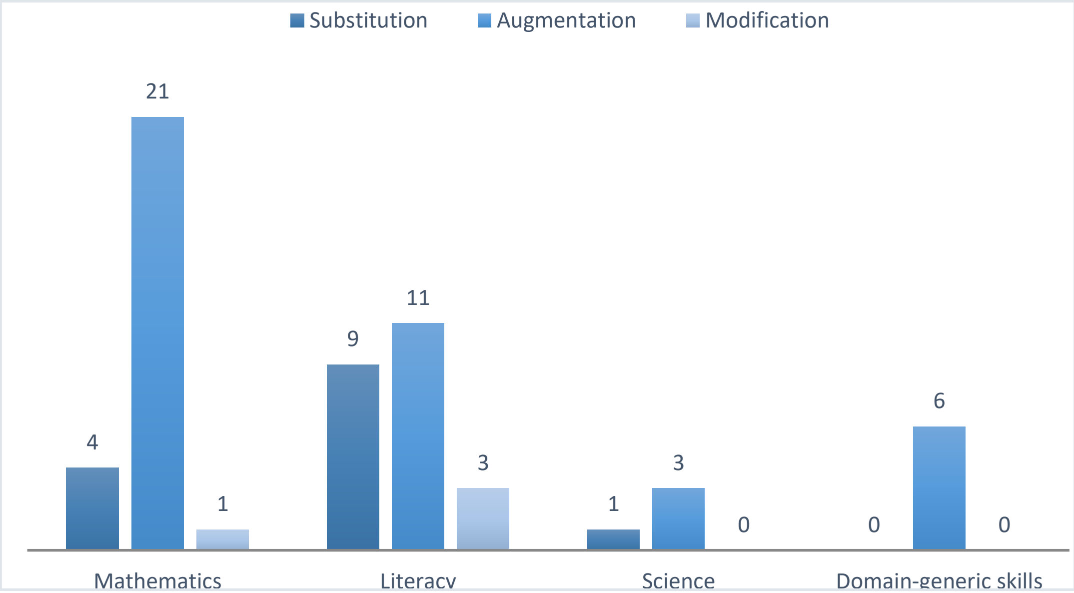

Figure 8: SAMR Level-based Distribution of Touchscreen Interventions across Various Learning Domains

As shown in Figure 8, the exploration of the domain-generic skills based on SAMR levels distribution showed a different pattern, compared to the other subject domains. In this regard, all of the studies targeting the effect of touchscreens on domain-generic skills had used these devices only at the augmentation level, with no studies integrating touchscreens at the substitution or modification levels.

5.5 Research Question 4

The final question in this study was posed in an attempt to find out if the outcome of learning with touchscreens varies across different levels of SAMR. To find the answer to this question, analyses were run separately for each of the learning outcomes with the integration level (i.e., SAMR levels) as the moderator. Table 4 presents the effect sizes for each of the learning outcomes when moderated by the levels of touchscreen integration.

Table 4: Moderating Effect of Touchscreens Integration Levels on Each of Learning Outcomes

Integration level Learning Outcome	Substitution	Augmentation	Modification	*Q*(*df*)
Mathematics	0.55*	0.64***	-0.89***	101(2)
Literacy	0.22	0.51***	0.32***	3.34(2)
Science	-0.19	0.86*	-	0.16(1)
Generic skills	0.024	-	-	-

*p < 0.05; **p < 0.01; ***p < 0.001.

The investigation of the moderating effect of SAMR levels on the influence of mathematics learning with touchscreens demonstrated a statistically significant result ($Q = 101$, $p = 0.00$). Based on the data, the effect sizes for touchscreen-based mathematics learning were found to be almost high at the augmentation level ($d = 0.64$, $p = 0.00$) and medium at the substitution level ($d = 0.55$, $p = 0.00$). This effect was demonstrated to be large and negative ($d = -0.89$, $p = 0.00$) when touchscreens were integrated at the modification level; however, this result should be interpreted with caution since there was only one study ($k = 1$) using touchscreens for mathematics learning at the modification level.

With regard to literacy, although the analysis was indicative of no significant variation in literacy learning effectiveness across the integration levels ($Q = 3.34$, $p = 0.18$), similar to mathematics learning, still the use of touchscreens at the augmentation level demonstrated the largest effect size ($d = 0.51$, $p = 0.00$). The two other levels, locating at the two end of the SAMR spectrum, showed low effect sizes, with the modification level showing a higher effect size ($d = 0.32$, $p = 0.00$), compared to the substitution level ($d = 0.22$, $p = 0.10$).

In relation to science learning, the results were suggestive of the moderating effect of integration level ($Q = 51.51$, $p = 0.02$). As the analysis indicated, the use of touchscreens at the augmentation level led to a high effect size for learning science ($d = 0.86$, $p = 0.03$). However, when the touchscreens were integrated at the substitution level, it had a small and even negative effect on science learning, which was not statistically significant ($d = -0.19$, p

= 0.36). The studies had integrated touchscreens for early science learning just at the enhancement levels; accordingly, there were no data for investigating touchscreen integration at the modification level. Regarding the generic skills, since the studies had integrated touchscreens only at the augmentation level, it was not possible to perform a sub-group analysis.

Chapter 6

6. Discussion

This section interprets and discusses the obtained results in relation to the research questions. The first subsection addresses the answers to the first two research questions, and the second sub-section discusses the answers to the second two questions.

6.1 Touchscreen Learning Effectiveness

The present research was an attempt to contribute to the literature by providing objective evidence on the overall effect of touchscreen technology on young children's learning and the factors moderating this effect. The results of the meta-analysis, which were based on both between-group and within-group analyses, were suggestive of the positive effect of touchscreens on young children's learning. The included studies had investigated the effect of touchscreens against traditional approaches (e.g., lecture instruction), physical manipulative (e.g., toys), and other technological devices (e.g., computer) or in the absence of these devices. Therefore, it can be concluded that young children show better learning performance when provided with touchscreen-based activities, compared to the time exposed to non-touchscreen activities or approaches. The medium effect size obtained in the present study based on 57 studies with 59 effect sizes (d = 0.48) is almost equal to the one reported by Xie et al. (2018) who performed a meta-analysis on 36 empirical articles with 79 effect sizes (d = 0.46). This consistency of findings can assure us of the reliability of the analysis and the positive learning impact of touchscreens.

The superiority of touchscreen-based pedagogical activities over non-touchscreen activities was also demonstrated in the integrated systematic review, which was suggestive of the positive influence of touchscreens on early learning when employed appropriately. As the integrated systematic review indicated, the effectiveness of touchscreen-based interventions varied depending on some factors/conditions. For instance, a touchscreen-based intervention could induce different learning effects based on learners 'age (Piotrowski & Krcmar, 2017). Regarding this, a moderator analysis was performed to objectively examine the effect of each of the potential moderators on the learning impact of touchscreens. The results of the moderator analyses revealed that the impact of touchscreens on young children's learning could vary depending on the learning domain, amount of adult's feedback during child's learning with touchscreens, and level of touchscreens integration (SAMR levels). Each of these moderators are discussed in more detail in the following sections.

6.2 Moderators of Early Learning with Touchscreens

The investigation of the learning effect of touchscreens based on each of the learning domains demonstrated that the use of touchscreens for learning mathematics and science had the largest effect size, compared to the other learning domains under investigation. These results denote that the use of touchscreens for mathematics and science instruction/learning brings about better learning outcomes, compared to using these devices for teaching/learning the other learning domains. The higher effectiveness of touchscreens as educational media for mathematics and science learning can be due to the fact that early mathematics/science learning is not limited to the rote learning of discrete facts (e.g., what is the answer to 2+3), instead it involves actively making sense of the surrounding world (McLennan, 2014), and touchscreens afford the creation of such learning experiences for young children. According to Fuson (2018), young children need concrete experiences/materials in order to better comprehend mathematical/scientific concepts. The tactile-based interface of the touchscreens allows for the creation of these concrete experiences by enabling children to directly manipulate the on-screen objects and exposing them to a perceptually more relevant and richer learning experience, which can, in turn, improve their mathematical/scientific understanding. The interactive nature of touchscreen apps subjects the young learners to dynamic mathematics/science learning opportunities and makes the concepts come alive. The touchscreen-based activities foster active learning by facilitating the direct manipulation of numerical representations, virtual objects, and verbal labels (Lee & Choi, 2020). Moreover, the multitouch nature of these educational media facilitates cognitive embodiment, which has been reported to bolster STEM learning (Duijzer et al., 2017; Disney, 2019; Weisberg & Newcombe, 2017). As acknowledged by the National Council of Teachers of Mathematics (2014), the use of virtual manipulatives can even help young children to develop an initial understanding of complicated mathematics concepts, such as algorithms, by extending their physical experience.

Furthermore, given the nature of mathematics, this subject of study is sometimes difficult to grasp for young children. This lack of understanding can result in the development of mathematics anxiety or a negative mindset about this subject in young learners (Dowker et al., 2019; Petronzi, 2016), thereby discouraging them from fully engaging in mathematics learning and practicing opportunities. However, the interactive features and visual or auditory effects of touchscreen apps can motivate young children to engage in mathematics learning (Xu et al., 2020) and gain interest in this subject as they begin to develop a deeper understanding of the mathematical concepts.

In relation to literacy, the results were suggestive of an almost medium effect size; however, this effect was lower than those obtained for mathematics and science learning. This might be due to the difference in the nature of these subjects. The dependence of STEM knowledge development on experiential and sensory learning may explain this higher effectiveness (Aladé et al., 2016; Han & Black, 2011). When it comes to literacy, it seems that touchscreens benefit early literacy learning by increasing young children's exposure to print and encouraging them to participate and engage in literacy learning activities by providing attractive visual cues and engaging physical experiences. As posited in the literature, emergent readers and writers gradually develop as they make discoveries and explore literacy materials, see print within the surrounding environment, interact with others (readers and writers), and observe how/why print is used (Strum et al., 2012; Sulzby & Teale, 1991). Accordingly, literacy develops as a result of experiences that facilitate meaningful interactions with language (both oral and written) (Sulzby & Teale, 1991). Regarding this, by providing multimodal, sensory, and cognitive stimulation experiences (Bedford et al., 2016) that are engaging and at the same time meaningful for young learners, touchscreens can provide an effective stimulus for early literacy development. For instance, Amorim et al. (2020) acknowledged the role of touchscreen app features not only in increasing students ' desire to literacy learning but also in decreasing the cognitive load required for gaining and automatizing the print-to-sound relationship skills.

In terms of domain-generic skills, the effect size was not statistically significant. This is while the literature is persistently confirmative of the contribution of technologies in enhancing learners 'engagement and motivation (Murphy et al., 2016; Wilkes et al., 2020). Even this potentiality of technologies has been enumerated as one of the factors resulting in improved learning outcomes. For instance, Martin et al. (2019) ascribed the higher learning outcome improvement in the group subjected to touchscreen technology to the remarkably higher motivation they gained as a result of learning with these devices. The variability of the skills classified under this domain might account for the obtained result. As stated previously, in this research, the studies investigating such learning-related outcomes/skills as engagement, visual and motor skills, and attention/motivation were all coded under domain-generic skills. Another reason that might explain this result is the lack of a standardized tool for assessing these skills or learning-related outcomes; these skills were mostly estimated based on the researcher-developed tools in the included studies. However, considering the small number of studies investigating this domain (n = 7), the results related to this category should be interpreted with caution (Borenstein et al., 2009).

The subject domain-related findings are consistent with those reported by Xie et al. (2018) who investigated the moderating effect of learning domains by categorizing the studies under STEM (including learn measuring, scientific trivia knowledge, or how to tell time) and non-STEM (entailing story comprehension, language arts, word learning, or puzzle problem solving) domains. In the mentioned study, the researchers found a higher effect size for STEM as compared to the non-STEM learning domains. Accordingly, they concluded that young children benefited more from learning with touchscreens when learning STEM domains than non-STEM domains.

The moderator analysis of age group demonstrated that the effect of touchscreens on early learning did not differ across the three age groups. However, similar to the results obtained by Xie et al. (2018), the results of the present study demonstrated that older children (age groups of 4-6 and 7-8 years) benefited more from learning with touchscreens than the younger ones (i.e., age group of 2-3 years). In terms of the effect size magnitude, the age groups of 4-6 and 7-8 years had a medium effect size, while the age group of 2-3 years showed a relatively small effect size. This result is in agreement with the results of a great number of studies reporting the higher effectiveness of learning with touchscreens among older children (e.g., Russo-Johnson et al., 2017). It is argued that the more developed cognitive processing and imagination of older children combined with the physical manipulation afforded by touchscreens account for this higher effectiveness (Diachenko, 2011; Xie et al., 2018).

The attainment of statistically significant effect sizes for all age groups is well indicative of the efficacy of touchscreens for early childhood education. The gestural interface of touchscreen technologies affords the reduction of the cognitive load of learning for young children by allowing for embodied cognition (Disney et al., 2019). Moreover, the use of touchscreens as mobile learning devices allows for the implementation of the Split Attention principle (Mayer & Moreno, 1998) and modality effect (Sweller et al. 1998), which underscores the significance of presenting information in more than one form for improving learning. In this regard, by affording the provision of learning materials in textual, pictorial, animated, or verbal forms, touchscreens can lower the cognitive load of learning for young learners, thereby improving both their learning outcomes and experiences (Lovato & Waxman, 2016).

The resulted related to the type of applications used for learning with touchscreens was also found to be non-significant. Nonetheless, the results of the sub-group analysis was suggestive of the superiority of edutainment apps over the purely educational and entertainment apps for young children's learning. As represented in their naming, edutainment apps are media that are designed with the intention of education through entertainment. These kinds of apps are characterized by a game-like format equipped with visual aids to entertain young learners as they engage with learning a subject. The playful nature of these apps is what keeps the young learners engaged in their learning task and motivates them to invest more effort in their learning process (Callaghan, 2018; Papadakis, 2018; Papadakis et al., 2017). Therefore, the achievement of a higher effect size for edutainment apps is well justified since the edutainment apps provide a transforming learning experience for the learners by offering the elements of educational and entertainment apps at the same time.

The moderating effect of app type has been already investigated and confirmed in two other meta-analyses investigating the impact of technology on learning (Chauhan, 2017; Sung et al., 2016). However, the app type in the mentioned studies was analyzed under the two codes of general-purpose apps (e.g., word processors or spreadsheets) and learning-oriented apps. To the best of our knowledge, there is no meta-analysis having investigated the moderating effect of app type in terms of educational, entertainment, and edutainment. As acknowledged by Nikolayev et al. (2021), the real educational benefits of the edutainment apps on children's learning are unknown. Therefore, the current meta-analysis contributes to the literature regarding the effect of app type on young children's learning by providing objective evidence in this regard. Although the game-based touchscreen learning activities can yield improved engagement and learning performance, a wide set of factors should be considered when designing and implementing these activities to ensure that they possess the necessary features that can foster learning among young learners. Some of the design characteristics that improve learning for young children include the motivational features that enhance children's engagement, scaffold provision for reducing cognitive load, and repetition opportunities via facilitating the practice of previously stimulated skills with different game mechanics to foster retention (Bringula et al., 2018; Outhwaite et al., 2019).

The investigation of the lengths of touchscreen-based interventions was not indicative of a statistically significant variation across the different levels of this variable. However, remarkably, the effect size was found to be medium in magnitude for all levels, except for 601-1,000 min which showed a small but insignificant effect size. Having a deeper look at the pattern of obtained effect sizes, one can see an increasing trend in the magnitude of effect sizes with the elongation of touchscreen intervention from 5-30 min to 101-300 min, with the former having the smallest (d = 41) and the latter (d = 60) having the largest effect size. However, from 101-300 min onward, there is a relatively descending trend in the effect size magnitudes, ranging from 0.41 to 0.45. This drop of effect size for the intervention length of 301-600 min up to 2,001-6,000, which are representative of long exposure times in our categorization, can be explained with regard to the novelty effect. Under the influence of the novelty effect and its subsequent increased engagement and motivation, learners achieve positive learning gains; however, this novelty effect wanes with accustomization over time (Jeno et al., 2019). Probably, being exposed to touchscreen-based activities for 301-6,00 min is the stage at which the novelty effect of touchscreens starts to wane away for the young learners and lower the learning effect of touchscreens. However, such an effect can shift back to an increasing trend or not keep up with a decreasing trend as a result of the familiarization effect (Rodrigues et al., 2022). Therefore, it can be stated that after young children's familiarization with the touchscreen-based pedagogical intervention, they achieve a recovery in their learning gains.

Similar to our findings, Chauhan's (2017) meta-analysis also demonstrated a variation in the pattern of effect size over various levels of technology exposure. In the mentioned study, the effect of technology on elementary students 'learning was reported to be high for the short duration of 1 week; however, the effect size turned small for intervention durations within 1 week to 6 months, before again becoming large for the long intervention durations of > 6 months. Accordingly, the findings of the mentioned meta-analysis are also indicative of the influence of novelty and familiarization effects on technology-enhanced learning.

Technology integration level was one of the factors that was found to moderate the effect of touchscreens on early learning. Regarding the enhancement levels, the use of touchscreens was found to have a larger effect size when used to augment learning than when used as a substitute. The achievement of a higher effect size for the augmentation level is quite justifiable since it offers greater opportunities for learners ’engagement by enhancing learning experience and making it more efficient. For instance, when an app is equipped with auditory feedback and allows for adjusting activities based on children's responses, it facilitates more independent and personalized learning and therefore enhances learning experience and outcomes by providing new potentials and engaging opportunities for young learners.

However, what is contrary to expectation is the result obtained for the moderating effect of the modification level of SAMR, which was very low and non-significant. An important point to consider is that the number of studies (k = 4) contributing data to modification level as a subgroup variable was very small. Accordingly, we cannot make any conclusion regarding the superiority of touchscreen integration at the enhancement level over the transformational level, and this area remains to be further explored in the future studies.

Based on the analysis, adult’s feedback during children’s learning with touchscreens was found to have a moderating effect on the learning effectiveness of the touchscreens. The sub-group analysis showed medium effect sizes when the children received low (d = 0.53) and moderate (d = 0.61) levels of adult’s feedback during their learning with the touchscreens, with those receiving the moderate feedback level showing a higher effect size. On the other hand, the provision of high feedback by adults/teachers was found to have a small effect size (d = 0.18). Accordingly, it can be inferred that children benefit the best from learning with touchscreens when they receive a moderate level of feedback from an adult (e.g., teacher and parents). This finding seems quite justifiable since feedback provision is a critical key to enabling the learners to achieve their learning goals, especially for young children who heavily depend on input for their guidance and development because of not having acquired self-assessment skills (Broda et al., 2019). As demonstrated in our results, a high feedback level had a small effect size for learning with touchscreens, while a moderate feedback level yielded the best outcome. Therefore, what matters is the provision of feedback at a logical amount and rate since a high feedback level may distract children from the learning activities, and a low feedback level may inhibit them from smoothly proceeding with the touchscreen-enhanced pedagogical activities.

The analysis of instructional grouping demonstrated no moderating effect for this variable. The lack of difference in the effect of touchscreens on young children’s learning depending on whether the touchscreen-based learning activities are performed individually, in pair, or in small groups can suggest the potential of touchscreens to be effectively employed in various instructional groupings. While the one-on-one use of touchscreens may prevent from distraction, the social interactions and scaffolding provided by the shared use of these devices during young children's learning can be also helpful (Blackwell, 2015). Regarding this, the teachers can benefit from the integration of touchscreens into their instructional activities in any of the one-on-one, paired, or small group settings depending on their students 'needs, the lesson to be presented, and the available facilities.

The results also revealed no significant moderating effect of learner type on the learning effectiveness of the touchscreens. This finding can be also indicative of the effectiveness of the educational use of touchscreens for both young children who had no need for special education and their peers with special educational needs. This is also consistent with the literature since in addition to the bulk of evidence confirming the effectiveness of using touchscreens for young learners without SEN, a variety of benefits have been also documented for the role of technologies in assisting young learners who need special education (Marsh et al., 2021). Although the effect sizes for both groups of students were medium in magnitude, this value was lower and not statistically significant for those with special needs. The lower non-significant effect size achieved in the present research for this group of learners can be due to the non-alignment of the selected touchscreen-based activities with the students 'needs and disabilities. The careful selection of the appropriate technology-enhanced learning task has been always emphasized as a matter of significant importance in achieving/establishing the favorable learning outcomes and experiences for young learners (Van Niekerk et al., 2018). This gains higher significance when it comes to SEN children because these young learners need extra support that can assist them to function to their maximum potential and thrive like their non-SEN peers (Morrison, 2020). The integration of a technology-based intervention that is not well aligned with the needs/skills and developmental stage of the SEN learners would add another layer of difficulty to their learning process and hinder their learning rather than facilitating it. The integration of technologies for assisting SEN learners requires more careful consideration of the individual learners to identify their specific needs/disabilities and implement the technology-enhanced instruction accordingly.

The examination of the experimental environment in which young children engaged with touchscreen-based learning revealed no significant moderating effect for this variable. Based on this result, it can be concluded that young children's learning outcome does not differ depending on the place in which they are learning with touchscreens. This can be explained by the potential of touchscreens to expose young children to learning experiences anywhere and anytime. This finding is not in line with the results obtained by Chauhan (2017) and Xie et al. (2018) who reported a significant moderating effect for the experimental setting in which the children were exposed to touchscreen-based learning. However, while the former study was suggestive of the higher effectiveness of technologies in informal learning environment (e.g., home, park, and outdoor places) than other more formal learning environments (e.g., classroom and laboratory), the latter study was indicative of the higher benefits of touchscreen learning when occurring in classrooms than in laboratories or other informal settings (e.g., home). A possible explanation for the findings of the current study is that young children today are brought up in a technology-rich environment with a decent amount of exposure to touchscreen technologies. The exposure of children to these devices both in formal and informal settings from early age may have removed this difference in effect since children are accustomed to working and learning with touchscreens in any place and under any condition.

6.3 Touchscreen Integration Level Status

The investigation of the status of touchscreen technology integration in early childhood educational research based on the SAMR framework revealed that 93% of the studies had integrated touchscreens at the enhancement levels of SAMR, namely substitution and augmentation, and only 7% had used touchscreens at the transformational level of modification, with no study integrating these devices at the redefinition level. Based on these results, it can be concluded that in the context of early childhood educational research, touchscreen-based activities are mostly used for enhancing learning, rather than transforming it. These results are consistent with those presented by Crompton & Burke (2020) who reported a higher use of mobile technologies at the augmentation level in the Pre-K and elementary grade levels and argued that these grade levels lack studies that target the affordances of mobile learning at its highest integration level. These results call for the implementation of the research that examines the use of touchscreen technology to transform learning for young children.

The examination of the level of touchscreen integration in each of the domain subjects/skills gave us a more detailed view of the trend of using touchscreens in early learning research. The distribution pattern of different integration levels across each of the subject domains demonstrated the augmentation level as the most frequently used level of touchscreen integration in all subject domains. Similarly, in the systematic review performed by Crompton & Burke (2020), touchscreens were reported to be integrated mostly at the augmentation level for mathematics and literacy instruction. As demonstrated in the moderator analysis, the integration of touchscreens at the augmentation level resulted in an almost large effect size for young children's mathematics learning. However, the use of touchscreens as only a substitute to the traditional mathematics pedagogical approaches showed a medium effect size. The integration of touchscreens for augmenting mathematics instruction facilitates the individualization and self-regulation of mathematics learning by providing the young learners with specific and immediate feedback about their performance (Crompton & Burke, 2020).

As argued by Puentedura (2013), at the modification level, students gain more educational benefits since they are involved in interactive and dynamic tasks that allow for creativity and going beyond the limitations of a traditional classroom. However, our results were indicative of a large and negative effect when touchscreens were used for mathematics learning at the modification level, which is quite contrary to what has been argued in terms of the benefits of this integration level. No generalization or conclusion can be made based on this finding because there was only one study integrating touchscreens at the modification level for early mathematics learning. More studies are needed to contribute data to the modification level in the subgroup analysis that enables the achievement of more accurate findings regarding the effect of early learning with touchscreens when integrated at the modification level.

With regard to literacy instruction, the sub-group analysis showed no significant difference across the different levels of technology integration for this subject domain. Therefore, it can be conducted that the use of touchscreens for early literacy instruction can be potentially beneficial at various levels of touchscreen integration. This could be due to the nature of literacy that lends itself to drill and practice, which can be accomplished by simply substituting technology with the more traditional approaches. Ebooks with limited features are a good example of using touchscreens as a substitute to the paper books. However, when ebooks are equipped with more engaging features, such as hotspots, animations, and feedback, they can augment children's literacy learning (Piotrowski & Krcmar, 2017; Zipke, 2017) and better improve their engagement and learning outcome.

Considering science, the studies had only benefited from touchscreen integration for the enhancement of learning, rather than its transformation, with the augmentation level showing a higher effect size than the substitution level. Science instruction can lend well to transformational learning via technology since these educational media can provide young learners with a platform to freely experiment with different scientific concepts and become aware of the applications of science in real-world problems (Gudiño Paredes, 2018). Therefore, it is required to pay more attention to the transformational use of touchscreen technology for early science learning.

In terms of domain-generic skills, the touchscreens were integrated at only augmentation level, with no study using these devices as a substitute or for modifying learning. Therefore, it was not possible to perform a sub-group analysis to examine if the learning outcomes of these skills vary across different levels of touchscreen integration. Regarding this, further studies are required to address this domain.

6.4 Conclusion

The results of the present research demonstrated that touchscreen technologies can afford the improvement of early learning in different domain subjects and skills. However, it is of fundamental importance to note that the presence of affordances does not warrant their fulfillment unless they are leveraged toward the pedagogical objectives. The sole provision of technology for the learners without prior planning cannot guarantee to make a difference (McKenna, 2012). Without such planning for the innovative integration of technology into the learning design and curriculum, technology can serve as only another route for delivering the same traditional content (Flewitt et al., 2015; Churchill, 2020). As argued by Flewitt et al. (2015), "if innovative uses of new technologies continue to remain absent from the school curriculum and from pedagogy, then we risk failing to turn on a powerful switch that can light up this generation's learning" (p. 17). Therefore, in order to establish the desired learning outcomes and experiences, efforts should be made to integrate technologies in a meaningful and purposeful manner (Mattoon et al., 2015).

As demonstrated in the present study, a variety of factors can affect the outcome of learning with touchscreen technologies. We specifically found that the effect of touchscreens on early learning can vary depending on the learning domain, adults' feedback level, and level of technology integration. Accordingly, when designing and planning for a technology-based pedagogy for early learning settings, teachers/educators need to consider several factors in relation to the learners, educational content/concepts, and learning context, in addition to the available facilities, to enable effective integration. What determines the quality of the learning outcomes and experiences is how effectively technologies are integrated into an educational setting. This is specifically important for early learning environments because young children are in their sensitive period of development (Frankenhuis & Walasek, 2020). In the present study, the use of touchscreens for augmenting early learning was found to exert the largest effect. Given the importance of this domain, it is required to perform further research targeting the integration of technology into early childhood educational settings both at the enhancement and transformative levels to enable comparing the effect of the two levels on early learning.

6.5 Research Limitations and Recommendations

The present research contains several limitations. First, the number of effect sizes for some of the moderators was so small. For instance, when performing a subgroup analysis for investigating the moderating effect of technology integration levels on mathematics learning outcome, there was only one effect size for the modification level. Certainly, it is not reliable to make a generalization based on only one single study. Accordingly, given the significant effect of technology integration on the success of a technology-enhanced pedagogy, it is recommended to perform further studies addressing this domain in the context of early childhood learning. Second, we could not investigate the different effects of various touchscreen app features/contents in terms of such aspects as the level of interactivity, visual attraction, visual/auditory feedback, or age-appropriateness. The variation of each of these features can affect the learning outcomes. Accordingly, further studies are needed to examine the effect of each of these features in different early learning environments. Third, the included studies were only limited to English language papers/dissertations/book chapters; therefore, the findings cannot represent the evidence obtained in other languages. Probably, a meta-analysis including studies in all languages and regions can present more generalizable results. Finally, it should be noted that since there were very few studies representing the transformational level of touchscreen integration, the results might be susceptible to potential false positives or negatives; therefore, caution must be exercised when using the results regarding the transformational use of touchscreens.

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