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The Influence of Young Children's Use of Technology on Their Learning: A Review

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ABSTRACT

This study aimed to conduct a systematic literature review on empirical studies of how technologies influence young children's learning. Eighty-seven articles published between 2003 and 2013 were identified through the Web of Science database. We employed content analysis to identify the research trends of this topic. "Technology evaluation," "adults' roles," and "teaching approaches" are three emerging research themes during 2008-2013. About one-third of the studies involved children who were from immigrant or low socioeconomic status families, or had special needs. The majority of the reviewed studies revealed that the technologies had positive effects on children's performance across developmental domains. Particularly, in social domain, most studies showed that technologies enhanced children's collaboration and interaction with others and their development of multiculturalism. We also propose a typology for conceptualizing the complexity of the relationships between technology use and children's learning. We argue that children's learning with technology is conditioned by several factors categorized into children, adults, and technology aspects. Moreover, a trend of examining children's development of digital literacy emerged, involving investigation of the skills needed for and perceptions of technology use. Lastly, while most studies viewed children as consumers of technology, their role as creators has been understudied and deserves more research attention.

Keywords

Early childhood education, Young children, Educational technology, Technology-assisted learning

Introduction

Contemporary young children are part of the generation of digital natives (Fleer, 2011; Prensky, 2001a, 2001b). Young children in this study refer to children aging from 0 to 8 years (Bredekamp & Copple, 1997). They live in a world enveloped by technologies and use technologies in their daily life (Hague & Payton, 2010; Plowman, Stevenson, Stephen, & McPake, 2012). Many countries recognize the increasing role of technology in children's lives. They emphasize the development of technology-integrated curricula that are developmentally appropriate for young children and that help to bridge young children's digital experiences at home and in school (Mawson, 2003; McKenney & Voogt, 2009; Plowman, Stevenson, McPake, Stephen, & Adey, 2011).

Because of the rapid development of technologies, they have changed children's lives and ways of learning, particularly in the past ten years. Researchers have urged a rethinking of the roles of technology in young children's development and consequently the development of learning theories and curricula that meet the needs of contemporary children (Fleer, 2011; Yelland, 2011). Although many researchers and educators have advocated for the importance of young children's learning with technology and devoted themselves to investigating and implementing technology-related practices, the influence of young children's use of technologies on their development is still controversial. Some researchers believe that the use of technologies may impede these children's social, emotional, physical, and cognitive development (e.g., Armstrong & Casement, 2000; Cordes & Miller, 2000), while others support the use of technologies in improving young children's development in the aforementioned domains (e.g., Clements & Sarama, 2003; Plowman & McPake, 2013; Plowman & Stephen, 2003; Yelland, 2011).

Such discussion surrounds one question about which early childhood educators have been concerned: are the technology-related practices developmentally appropriate for young children (Radich, 2013)? In terms of developmentally appropriate practices, knowledgeable adults play important roles in scaffolding young children's learning within the zone of proximal development (Bredekamp & Copple, 1997; Vygotsky, 1978). Researchers are thus concerned with the learning effect on children between adult-facilitated and technology-assisted learning. For example, de Jong and Bus (2004) conducted a study to compare children's learning outcomes after they listened to adults' storybook reading and read e-books on their own. Another example of developmental appropriate practice is that children learn abstract concepts through manipulating concrete objects (Dunn, 2001; Hsin, 2012). Researchers have thus debated the effects of manipulating physical materials and virtual materials on children's learning of science or mathematic concepts (Clements & Sarama, 2003; Zacharia, Loizou, & Papaevripidou, 2012). Moreover, promoting the development of social skills is considered one of the important developmentally appropriate practices for young children (Bredekamp & Copple, 1997). Some researchers have argued that technology may impede young children's social skills because children develop these skills through in-person interaction, and their use of various technologies keeps them from such interaction (Armstrong & Casement, 2000). In contrast, some researchers have indicated that technology in fact promotes children's social development in various ways (Infante et al., 2010). Researchers on both sides argue that the practices they advocate are developmentally appropriate. However, such binary discussion can lead researchers and educators to overlook the complex relationships between children's use of technology and their learning. We therefore aim to provide a typology for effectively conceptualizing the interplay among critical factors that influence children's learning with technology.

Another concern which motivated our examination of the relationships between technology use and children's learning is a lack of a complete, in-depth picture of the past ten years that shows (a) how technologies play a role in children's learning across the aforementioned four developmental domains, and (b) what research themes and methods researchers have focused on. Although researchers have debated on and raised the importance of this topic for the past ten years, there has been little attention given to a systematic literature review of the empirical studies that have been conducted to understand young children's learning with technology in different developmental aspects. Also, an overview of the research purposes and methods of these empirical studies is needed. A more complete picture of this topic would encourage researchers to fill the research gaps and to address issues that have not been fully elaborated or supported with evidence. It would also consequently support the development of technology-integrated curricula.

Researchers have paid attention to not only how technologies affect young children's learning across domains, but also how young children learn to use a variety of technologies, that is, the development of digital literacy. In comparison with the traditional view of literacy, such new forms of literacy emphasize children's abilities to comprehend and create multimodal digital texts in order to communicate with texts or others (Bawden, 2008; Lankshear & Knobel, 2008). There has been an emergent research trend in digital literacy. However, how preschoolers and kindergarteners develop their digital literacy and how they enact their roles as creators rather than consumers (Taylor, 1980) of technologies have, as yet, been understudied.

In response to the aforementioned needs, we have conducted a systematic literature review and initiated an evidence-based discussion on how technologies influence young children's learning. We asked the following research questions:

- How do technologies influence young children's learning across different developmental domains?
- What are the purposes and methods focused on by researchers when conducting studies of this topic?
- What are the key factors that influence children's learning with technology?

Method

Paper selection

In this review, the Web of Science database was used to search for articles regarding young children's learning with technology published from 2003 to 2013. The search of the literature was carried out in May 2013. The reviewed articles were identified through the following procedures. First, a set of technology related keywords was used in combination with the other set of keywords regarding target age groups by employing the Boolean operator "AND." The technology related keywords were *technology/technologies*, *computer/computers*, *media*, *medium*, *multimedia*, *digital literacy/literacies*, and *multimodal/multimodality*. The keywords related to target age group were *young child/children*, *preschooler/preschoolers*, *kindergarten/kindergartener*, *early child/childhood*, and *early year/years*. The Boolean operator "OR" was utilized to combine the keywords within the same set. In addition, the truncation search technique was adopted to cover the variations of keywords. For example, *technolog** was used to search for literature that included the word *technology* or *technologies* in the target search fields. Because the emphasis of this review is on children's learning, the results of the keywords search were limited to the "Education Educational

Research" category in the database. Moreover, only peer-reviewed journal articles were selected to ensure the quality of the studies reviewed. These articles are all indexed in Social Science Citation Index (SSCI). Lastly, targeted articles had to be written in English due to a lack of comprehension of other languages. The database search resulted in 273 articles for further selection. It should be noted that the articles selected for the current review are not meant to be inclusive, but are used to explore the emergent issues of this line of research during the past decade. It might not be appropriate to generalize the results of this study to the research field of technology-supported education in early childhood.

Following the database search, the researchers read through the titles and abstracts of the articles to select target papers that met the following criteria: (a) they should be empirical studies that investigated the effectiveness of a technology on children's learning or surveyed the relationships between technology use and children's learning, (b) at least one technology is adopted or reported for children's learning, (c) the age of the participating children is under 8 years old, and (d) the full text of the article should be available either in paper or electronic format. If sufficient information for selecting the articles was not provided in the abstracts, the researchers then went through the major parts of the articles (e.g., methodology and results) to make the judgments. If a study investigated the influence of technology on learning across different age groups, only the instructions and learning results in relation to the children under 8 years old were reviewed. However, the article was excluded if the target children were not the main focus of the study among different age groups. Furthermore, if the main focus of the research was on technology development or instructional design and no essential outcome data were provided, the article was excluded as well. After this selection process, 87 articles were identified for this review. A complete list of the reviewed articles can be downloaded from http://goo.gl/bT7DsK.

Paper analysis

The identified articles were analyzed using a content analysis technique. NVivo 10 analysis software was utilized to facilitate the development of the coding scheme. First, 18 articles were randomly selected and read by the authors to develop an initial coding scheme in accordance with the research questions. Next, another 54 articles were randomly selected and assigned to the first and second authors. Each author coded 27 articles independently. When there was a need to add, remove, merge, or modify a code, the authors discussed the code until a consensus was reached. After both authors completed the previous coding process, the remaining 15 articles were coded by both authors independently. The inter-coder agreement was calculated for the coding results of these 15 articles. Agreement reached 87 %.

Several rules were applied to the coding task. When there was more than one study reported in the article, only the study/studies that met the review criteria would be coded (e.g., Manches, O'Malley, & Benford, 2010). If all the studies met the review criteria, they were coded separately as individual articles (e.g., Magnan & Ecalle, 2006). If more than one study was conducted in an article but the results were integrated among studies, those studies were coded as one article (e.g., McPake, Plowman, & Stephen, 2013). As a result, 94 studies from 87 articles were analyzed. Participating children in these studies aged from 0 to 8 years. Children's use of technology refers to their engagement in activities involving various types of technology and concomitant development in various domains. The types of technology identified from these studies include information and communication technology (ICT) (e.g., computer programs and Internet), multimedia (e.g., E-books and TV) and digital devices (e.g., interactive whiteboard and robot).

Coding scheme

The coding structure developed through the content analysis consists of five categories, with each including several sub-categories.

Research purposes

Six research purposes were identified. If a study involved more than one research purpose, only the major one was coded. These research purposes are described as follows.

- Technology evaluation: Investigate the influence of technologies on children’s learning.
- Technology vs. tradition: Compare the influence of technology-assisted learning and traditional ways of learning (without technology).
- Teaching approaches: Compare the influence of different teaching and learning approaches or models embedded in the design of a technology. For example, a study compared the effects of systematic and unsystematic phonics training on language learning (De Graaff, Bosman, Hasselman, & Verhoeven, 2009).
- Mechanism design: Compare the influence of different mechanism designs adopted in the same technology. For example, a study revealed how different interfaces (i.e., individual and paired control) led to different behavior of children (Druin et al., 2003).
- Adults’ roles: Investigate adults’ roles in children's technology use, including adults’ facilitation of children’s engagement in using technology, adaptation of their teaching to respond to children’s learning with technology, and perceptions of children’s technology use.
- Consumers vs. creators: Explore the ways in which children learn content delivered by technologies (consumers) or create digital texts and write program to solve problems (creators).

Research design

Five major research designs were identified including: experimental design (with random assignment), quasi-experimental design (without random assignment), one group pre/post-test or post-test only design, case study, and survey. Any research designs other than these five methods were categorized as “Others.” If a study adopted more than one research design, only the major one was coded.

Research participants

Children were grouped into those with a general background and those with diverse backgrounds. Children were categorized as diverse if they were from immigrant or low socioeconomic status families, or had special needs (e.g., reading difficulties, dyslexia, developmental delay, Autism, Down syndrome, or pre-, peri- and post-natal complaints).

Developmental domains

Four developmental domains were used to classify the learning results: the cognitive, social, emotional, and physical domains. Under the cognitive domain, the results were further categorized into different learning areas including language and literacy, digital literacy, math, science, cognitive abilities, and others. When there were multiple results reported in a study, each result was coded into a developmental domain. If the result was related to the cognitive domain, the specific area under the cognitive domain was coded.

Learning results

Each learning result was also categorized into positive, negative, no difference, or depends. When a result was coded as depends, it indicates that the effectiveness of the technology for children’s learning was conditional by various factors (e.g., children’s age, adults’ roles, or mechanism designs of technology). The conditional factors were also coded for further analysis and discussion.

Results and discussion

The analysis results are presented in the following subsections. First, an overview of the descriptive statistics is provided. Second, cross-analysis results between reviewed categories, including research purpose and research design as well as developmental domains and learning effectiveness are reported. Following the quantitative analysis results, the in-depth analyses and discussion are organized into four parts: a typology for conceptualizing young children's learning with technology, an emergent discussion of digital literacy, the supports of technology for children's social development, and children's roles as creators of technologies.

Overview of the reviewed studies

Among the 87 reviewed articles, 23 were from 2003 to 2007 and 64 were from 2008 to 2013. The number for the latter period is more than 2.5 times that of the former period. This indicates an increasing interest on this topic during the last six years. All of these articles were published in 43 peer-reviewed journals. More than half of the articles were published in nine journals: *Computers & Education* (14 articles), the *Journal of Computer Assisted Learning* (7 articles), the *Journal of Educational Computing Research* (4 articles), *Reading and Writing* (4 articles), the *Australasian Journal of Early Childhood* (3 articles), the *British Journal of Educational Technology* (3 articles), the *Journal of Research in Reading* (3 articles), *Reading Research Quarterly* (3 articles), and *Research in Developmental Disabilities* (3 articles).

Table 1 provides an overview of the 94 studies in this review. The majority of the studies aimed to evaluate the influence of technologies on children's learning, compare the effectiveness of interventions with and without technology-assisted learning, and investigate the roles of adults in children's use of technology. Moreover, "technology evaluation," "adults' roles," and "teaching approaches" are three emerging research topics during 2008-2013. In addition, more than half of the studies employed either experimental or quasi-experimental design, while more than a quarter of them were case studies. Lastly, about one-third of the studies concerned the learning of children of diverse backgrounds, including those from immigrant or low socioeconomic status families (13 studies) or had special needs (19 studies). This finding implies that researchers have noticed the affordances of technology for educators to scaffold the learning of these children.

Table 1. Research purposes, research design, and research participants by publication year

		Publication Year		
		2003-2007 n (%)	2008-2013 n (%)	Total n (%)
Research Purpose	Technology Evaluation	9 (9.6)	26 (27.7)	35 (37.2)
	Technology vs. Tradition	13 (13.8)	12 (12.8)	25 (26.6)
	Teaching Approaches	0 (0.0)	7 (7.4)	7 (7.4)
	Mechanism Design	2 (2.1)	4 (4.3)	6 (6.4)
	Adults' roles	1 (1.1)	15 (16.0)	16 (17.0)
	Consumers vs. Creators	1 (1.1)	4 (4.3)	5 (5.3)
Research Design	Experiment	4 (4.3)	24 (25.5)	28 (29.8)
	Quasi-experiment	12 (12.8)	10 (10.6)	22 (23.4)
	One group pre/post-test or post-test design	2 (2.1)	2 (2.1)	4 (4.3)
	Case study	7 (7.4)	20 (21.3)	27 (28.7)
	Survey	1 (1.1)	8 (8.5)	9 (9.6)
	Others	0 (0.0)	4 (4.3)	4 (4.3)
Research Participants	General	15 (16.0)	47 (50.0)	62 (66.0)
	Diverse	11 (11.7)	21 (22.3)	32 (34.0)

Cross-analysis results

Research purpose vs. research design

Table 2 shows the cross-analysis results of the research purposes and research designs. When the studies focused on describing how young children used technology in situ, they mostly adopted a case study design, followed by the survey method used to provide generalizable patterns of children's technology use. It should be noted that these survey studies either collected data reported by adults (i.e., parents or teachers) or utilized data from nationwide databases. The experimental and quasi-experimental designs were employed by almost all studies aiming to compare the effects of technology-supported learning with conventional approaches and those aiming to compare different technology designs (i.e., embedding teaching approaches and mechanism designs). Although experimental and quasi-experimental designs were also adopted by the majority of the studies that investigated the influence of adults' roles in learning, studies that applied the case study method could provide in-depth observation of adults' roles in children's use of technology. With the least studied topic "consumers vs. creators," all studies were conducted using the case study method.

Table 2. Frequencies and percentages of research purposes and research designs

	Research Design					
Research Purpose	Experiment n (%)	Quasi-Experiment n (%)	One group pre/post-test or post-test design n (%)	Case study n (%)	Survey n (%)	Others n (%)
Technology Evaluation	2 (2.1)	2 (2.1)	4 (4.3)	15 (16.0)	9 (9.6)	3 (3.2)
Technology vs. Tradition	8 (8.5)	15 (16.0)	0 (0.0)	1 (1.1)	0 (0.0)	1 (1.1)
Teaching Approaches	7 (7.4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Mechanism Design	3 (3.2)	2 (2.1)	0 (0.0)	1 (1.1)	0 (0.0)	0 (0.0)
Adults' roles	8 (8.5)	3 (3.2)	0 (0.0)	5 (5.3)	0 (0.0)	0 (0.0)
Consumers vs. Creators	0 (0.0)	0 (0.0)	0 (0.0)	5 (5.3)	0 (0.0)	0 (0.0)

n: Total number of studies

We further applied a chi-square test and found the associations between research purpose and research design significant ($\chi^2 = 43.39$, $p < .001$). Researchers used the design of experiments (i.e., experimental, quasi-experimental, and one group pre/post-test or post-test design) more often than non-experiments (i.e., case study, survey, and others) when they compared technology-assisted and traditional ways of learning (AR = 4.1) or the effectiveness of technologies designed on the basis of different teaching approaches or mechanism (AR = 2.7). In contrast, the design of non-experiments outnumbered experiments significantly when the research purposes were "technology evaluation" (AR = 5.2) or "consumers vs. creators" (AR = 2.7).

Developmental domains vs. learning effectiveness

Among 94 studies, 83 investigated the influence of technology on cognitive learning. Social learning is the second most frequent developmental domain emphasized by the studies (n = 19), followed by the emotional domain (n = 12) and the physical domain (n = 2). Most of the studies targeted one domain (n = 76), several studies considered the influences of technologies on two domains (n = 15) (e.g., cognitive and social domains or cognitive and emotional domains), and only three discussed results across more than three domains. Within the 83 studies that emphasized cognitive learning, different areas of learning were supported including language and literacy (n = 47), digital literacy (n = 19), math (n = 12), science (n = 6), and general cognitive abilities (e.g., problem solving, working memory, self-regulation, and creativity) (n = 12). In other words, cognitive learning is the most investigated domain, and under this domain, the field of language and literacy learning has attracted the most attention. The potentials of using technology to support learning in other domains and other cognitive fields are needed. As for learning results, 61 studies reported positive findings, 24 reported no differences, and only 2 reported negative outcomes. It seems that the majority of the studies indicated an overall positive effect of technologies on learning. However, it should be noted that two biases might contribute to the overwhelmingly positive results. One is that authors are more likely to submit papers with positive learning outcomes. The other is that the reviewed papers were limited to educational research. Papers in other fields (e.g., pediatric and psychology) may concern more about negative effects and are suggested to be included in future studies. Moreover, another important finding is that more than half of the studies (n = 51) found that the effect of technology-supported learning is conditional. An in-depth exploration of the conditional factors is elaborated in the following subsection. Table 3 and Table 4 show the results of cross-analysis between developmental domains and learning effectiveness. Because a study with more than one result would be coded into different categories, only frequencies are provided to illustrate an overall distribution of developmental domains by learning effectiveness.

Table 3. Frequencies between developmental domains and learning effectiveness (n = 94)

	Learning Effectiveness			
Developmental Domain	Positive	Negative	No difference	Depends
Cognitive aspect	53	2	20	47
Social aspect	13	1	4	3
Emotional aspect	10	0	1	1
Physical aspect	2	0	0	0

Table 4. Frequencies between cognitive domain and learning effectiveness (n = 83)

	Learning Effectiveness			
Cognitive Domain of Development	Positive	Negative	No difference	Depends
Language and literacy	26	1	16	32
Math	8	0	2	7
Science	4	0	1	3
Digital literacies	17	1	0	5
Cognitive abilities	7	0	2	3
Others	2	0	0	0

A typology for conceptualizing young children's learning with technology

As mentioned earlier, we found that the influence of technology on children's learning is conditional. We then further identified several conditional factors and categorized them into three key components: adults, children, and technology. Moreover, we proposed a typology that displays the complex relationships among the three components (see Figure 1). This typology shows the reciprocal interplay between children and technology, and adults play as mediators between children and technology. It should be noted that the effects of these factors are not conclusive. We did not attempt to synthesize these effects but highlighted potential avenues for future research.

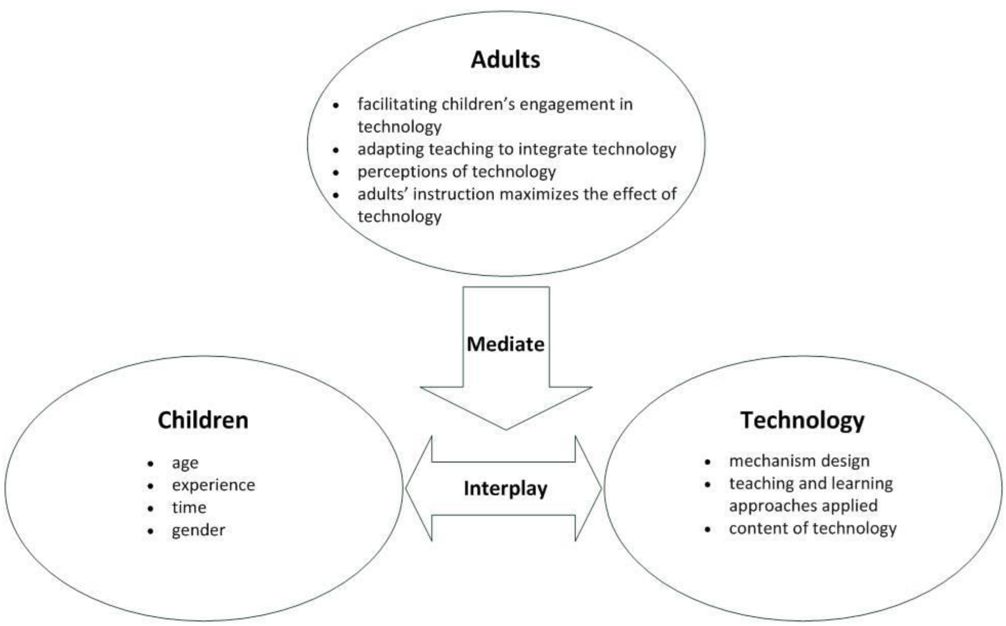

Figure 1. A typology of factors that influence children's learning through technology.

The children aspect

The impact of technology on children's learning is conditional by children's age, experience, time spent using the technologies, and gender. In terms of children's age, when comparing the effect of the technology-related intervention on children of different age groups, older children tended to outperform younger children (e.g., Andrews, Woodruff, MacKinnon, & Yoon, 2003; Cviko, McKenney, & Voogt, 2012; Korat & Shamir, 2012), or the intervention had a statistically significant effect on older children but not on younger children (e.g., Manches et al., 2010; Watson & Hempenstall, 2008)

Also, children's experiences, including (a) prior knowledge and (b) computer access at home, were related to their technology-related learning. Children with greater prior knowledge made more progress in their performance after using technology. For example, Zacharia, Loizou, and Papaevripidou (2012) found that kindergarteners who had correct prior knowledge of a balance beam learned more from the experimentations regardless of the different ways in which they conducted the experiments. In contrast, a study suggested that having more prior knowledge may be a disadvantage for children's technology-related learning. Levy (2009) revealed that young children's accumulated knowledge in print reading in school may impede their development of reading multimodal computer texts. She found that children were confident using strategies to read computer texts before entering school. However, after learning in school that reading was "the decoding of print in school-based books" (p. 88), their confidence in reading computer texts decreased over time.

Another factor is children's computer access at home. Studies have shown that children's computer access at home is positively correlated with their performance in reading (e.g., Bittman, Rutherford, Brown, & Unsworth, 2011; Magnan & Ecalle, 2006), math (e.g., Judge, Puckett, & Bell, 2006), cognitive development (Fish et al., 2008), and computer-esteem and skills (Hatzigianni & Margetts, 2012; Sackes, Trundle, & Bell, 2011). However, Puckett and Bell (2006) found that children's frequent use of computer programs for reading was negatively correlated with their reading achievement. They suggested that young children with low reading achievement would benefit more from teachers' reading instruction than from computer programs for reading.

Time is another factor that influences children's learning with technology. Time factors include (a) the treatment retention effects and (b) the time that children spent using technologies. For example, Kyle et al. (2013) investigated the retention effect of a computer-assisted reading intervention and found children maintained their gains on reading skills four months after the intervention. Also, studies have revealed that the more time that children spent on the technology-supported intervention, the better performance they had (Lonigan et al., 2003; Segers & Verhoeven, 2005). However, Ryokai, Farzin, Kaltman, and Niemeyer (2013) found that some children in their study showed negative performance slopes regarding the ability to track multiple objects over computer-assisted intervention sessions.

Gender difference in computer-related performance is another topic that researchers emphasized. The effect of technology use for boys and girls varied. A study indicated that girls had a higher developmental rate of computer skills than boys (Sackes et al., 2011), while another study found that boys had better learning outcomes than girls after playing a noncompetitive mathematics game (Wei & Hendrix, 2009).

Other children's backgrounds, such as second language learners and children's social economic status, are factors that researchers examined when investigating topics regarding how technology influences children's learning (e.g., Kim & Chang, 2010; Sackes et al., 2011).

The adults aspect

The role of adults is another critical component in the typology for conceptualizing the interplay between children's learning and their technology use. We discuss the four aspects of adults' roles in children's technology use as follows. First, adults facilitate children's engagement in using technology to learn (e.g., Eagle, 2012; McKenney & Voogt, 2009). Children learned more from using technology when adults provided them with a safe climate, encouraged them to participate in conversation, involved them in establishing the goals of the activity, and maintained their interaction with the adults and with the technology.

Second, adults adapt their teaching to respond to children's learning with technology. For example, Clements and Sarama (2008) stated that children gained most from a technology-integrated, mathematics curriculum in which the teachers adapted the learning activities based on their understanding of the learning trajectories and the children's prior knowledge. Similarly, Shamir, Korat and Barbi (2008) found that teachers' adaptive instruction for technology-assisted learning would lead students to better learning outcomes. In other words, when teachers instructed children to read e-books with their peers, the children showed more improvement in their reading skills than those who read e-books alone.

Third, adults’ perceptions of children’s technology use influence how they support or do not support their children’s learning through technology. Some adults had a positive attitude toward technology and made efforts to integrate technologies into their curriculum or to engage children in technology-related activities (e.g., Cviko et al., 2012; Fessakis, Gouli, & Mavroudi, 2013). In contrast, in Wolfe and Flewitt’s (2010) study, most of the participating parents and teachers were concerned that children’s frequent use of technology may impede their development, and these adults either restricted the amount of time their children could spend using computers or did not encourage or facilitate children’s technology use.

Fourth, adults’ teaching in conjunction with technology-assisted learning maximizes the effect of technology on children’s learning, whereas adults’ teaching and technology-assisted learning alone had less effect on children’s learning gains (Eagle, 2012; Segal-Drori, Korat, Shamir, & Klein, 2010). Segal-Drori et al. (2010) found that children who read electronic books and received teachers’ instruction that promoted emergent reading outperformed those children who read electronic books without adult instruction. They also outperformed those children who read printed books with adult instruction.

The technology aspect

Three technology-related factors are discussed: the mechanism design of the technologies, the teaching and learning approaches applied to the design of the technologies, and the content of the technologies.

Studies have revealed the impact of different mechanism designs of a technology on children’s behavior (e.g, Druin et al., 2003; Korat & Shamir, 2012). For instance, Druin et al. (2003) found that different designs of interfaces supported different aspects of children’s collaborative experiences. In their study, they developed two collaborative conditions for paired children to work on computer tasks. In one condition, each of the paired children used an individual mouse and controlled the interface independently; in the other condition, each action needed to be confirmed by the other paired child. The authors found that the former, flexible condition led children to talk more about the content of the tasks. The latter, structured condition led the children to talk more about the shared goals and function of the mouse.

In terms of applying different teaching and learning approaches in the design of the technologies, researchers have examined the effects of computer programs or games developed on the basis of different teaching and learning approaches. Examples of these approaches are: systematic phonics training versus unsystematic phonics training (De Graaff et al., 2009), synthetic phonics intervention versus analytic phonics intervention (Comaskey, Savage, & Abrami, 2009), bottom up literacy training versus top down literacy training (Helland, Tjus, Hovden, Ofte, & Heimann, 2011), whole language games versus phonics skills games (Segers & Verhoeven, 2005), a prediction-observation-explanation (POE) model science game versus a non-POE model science game (Hsu, Tsai, & Liang, 2011), and approximate number training versus exact number training (Obersteiner, Reiss, & Ufer, 2013).

Lastly, the content of the technologies also plays a role in children’s development. Conners-Burrow, McKelvey, and Fussell (2011) indicated that children’s viewing of age-inappropriate content of television programs (i.e., PG-13 or R-rated videos and movies) was related to their aggressive and hyperactive behavior problems in the classroom. They stressed that it was the content of the television programs rather than the amount of time children spent watching television that had an impact on the development of their social skills.

Emergent discussion on digital literacy

Among the research topics devoted to the understanding of children’s cognitive development and technology use, children’s literacy learning was the most studied. While most researchers emphasized such traditional ideas of literacy, some have explored new forms of literacy made possible by the development of digital technologies and the internet: digital literacy. These researchers examined young children's digital literacy development from two aspects: (a) skills and competences needed to use technology, and (b) perceptions of technology use.

Skills and competences needed to use technology

The majority of the studies related to young children's digital literacy development involved the skills and competences that children had or needed to use technology including:

- Children's ability to use a mouse and touchscreen: Studies have been conducted to examine the ways to improve young children's computer skills with a mouse or touchscreen. For example, Shimizu, Yoon and McDonough (2010) developed a training program that was found to be effective in reinforcing developmentally-delayed preschoolers' point-and-click skills with a mouse and their eye-hand coordination. Donker and Reitsma (2007) compared two ways of using a mouse, drag-and-drop versus click-move-click, and found that the former resulted in fewer interaction errors and was more appropriate for kindergarteners and first graders.

- Children's learning of computer programming (Fessakis et al., 2013; Matthews & Seow, 2007): Studies have revealed that young children can learn the basic concepts of programming. In Fessakis, Gouli and Mavroudi's (2013) study, the participating kindergarteners were able to use commands to solve programming problems. Through the intervention program, kindergarteners learned basic programming concepts, including "command, sequential execution of commands, program, logical errors, testing and debugging of programs" (p. 94).

- The digital tools and technology-related literacy practices that children had at home (Plowman, Stephen, & McPake, 2010; Plowman et al., 2011): Researchers adopted a sociocultural approach to literacy learning and found that preschoolers encountered technology and read digital texts in their daily familial life. These children knew how to play DVDs, use remote controls to locate and change TV channels, use digital cameras, mobile phones or tablets to take pictures, resize windows on a computer, type letters and use drawing tools on computers, play games on computers, mobile phones or tablets, and so on. Children had accumulated the knowledge of digital literacy from daily technology-related practices at home. Researchers are concerned with the discrepancy between home and school regarding children's learning of digital literacy. This is because teachers in preschools often do not draw upon children's knowledge of digital literacy in order to advance their learning with technology (Plowman et al., 2010).

- Children as creators of multimodal, digital texts: McPake, Plowman, and Stephen (2013) described that a three-year-old boy in the U.S. was proficient in taking photos. He and his five-year-old sibling sent photos and emoticons when making video calls to their relatives in Australia. The researchers stated that the boy learned to develop a storyline "in visually meaningful and engaging ways, beginning to develop the skills to create new and (socially) valuable narratives" (p. 427). In O'Mara and Laidlaw's (2011) study, young children were able to create multimodal stories consisting of audio narratives, pictures, video clips, and digital drawings and texts. Furthermore, they had the ability to transform content from one mode (sign system) to another to make sense of and communicate with multimodal texts. Mills (2011) indicated that this transformation process, called transmediation, was demonstrated by eight-year-olds in her study. The children translated written texts into images and their drawings into a film. They also transformed their handwritten comics into digital online comics. The role of children as creators of technology will be discussed in a later subsection.

- Children's ability to read and comprehend multimodal, digital texts: Studies have revealed that young children are able to use multimodal cues to comprehend the meaning within the contexts of digital texts. Such multimodal cues include pictures, symbols, sound, images, and gestures, which were used across a variety of technologies, such as TV, computers, mobile tablets, mobile phones, game consoles, and touch screens (e.g., Levy, 2009; McPake et al., 2013).

- Children's ability to search for information online: Young children are capable of using search engines, such as Google and YouTube to locate information they need. For example, Davison (2009) described that a six-and-half-year-old boy used Google to search for more information about the lizard he learned from a book. O'Mara and Laidlaw (2011) found that 3- and 5-year-olds were interested in selecting and viewing online programs and video clips on YouTube or other internet resources.

Perceptions of technology use

The other aspect of children's digital literacy development is their perceptions of technology use, including (a) perceptions of the social and cultural roles of technologies, and (b) perceptions of their capability to use computers, that is, their computer self-esteem. Studies have shown that preschoolers had learned the social purposes of technology (McPake et al., 2013; Plowman et al., 2012). These social purposes included communication, maintaining social ties, entertainment, study, and adults' employment. With regard to children's learning of the cultural conventions of using technology, McPake et al. (2013) described that when making a video call, a three-year-old boy considered his communication partners' viewpoints and emotions, and then he chose the most appropriate photos to send to them. His behavior demonstrated that he was aware of the culturally appropriate ways of making a video call. In terms of children's development of their computer self-esteem, it was positively correlated with their computer access at home and in school (Hatzigianni & Margetts, 2012).

Technology supports children's social development

Some researchers believe that children at a young age should avoid using technology because it keeps them from interacting with others and therefore impedes the development of their social skills (e.g., Armstrong & Casement, 2000; Cordes & Miller, 2000). In contrast to this viewpoint, we found that only one reviewed study revealed that the use of a touchscreen increased children's behavior of pursuing individual goals instead of collaboratively achieving the same goal, implying that the use of technology may hinder children's social development (Romeo, Edwards, McNamara, Walker, & Ziguras, 2003). Most of the studies, however, showed that various technologies support children's social development (see Table 3).

Young children's social development was supported by technologies in three aspects. First, a variety of technologies enhanced children's collaboration and interaction with peers. For example, Infante et al. (2010) found that a video game, which was designed for multiple players to use one computer screen and several input devices, encouraged kindergarteners to collaborate and communicate in order to complete the game tasks. Lim (2012) examined kindergarteners' social behavior in the computer area in a classroom. The author argued that in that area, the kindergarteners learned useful information and engaged in learning through active interaction with their peers.

Second, the technologies used at home facilitated adult-child interaction and maintained family relationships. Researchers described how young children worked with adults (e.g., parents, grandparents, relatives) to achieve the shared goal of the technology-related activity and reinforce their ties with family members. For instance, the 3-6-year-old grandchildren and the grandparents helped each other in computer activities. While the children taught their grandparents how to play a computer game, the grandparents helped the children with the linguistic and cultural knowledge needed to play the game (Kenner, Ruby, Jessel, Gregory, & Arju, 2008).

Third, technology was related to young children's development of multiculturalism. As Perry and Moses (2011) indicated, television programs in the U.S. reinforced immigrant children's development of their cultural identification with their country of origin, Sudan. However, in terms of the effect of the television programs in changing young children's attitudes toward the non-majority, Persson and Musher-Eizenman (2003) indicated that regardless of how the show was presented (i.e., real people, animation, puppets), after watching the show, the 3- to 6-year-olds in the U.S. maintained their preference for White over people of other ethnic groups.

Children's roles as consumers and creators of technologies

As shown in Table 1, unlike most of the studies that viewed children as consumers of pre-designed learning content delivered by technologies, only five studies explored and observed children's use of technology as creators, either by creating digital artifacts such as multimodal texts, paints, photos, and videos (e.g., McPake et al., 2013; Mills, 2011) or by writing or modifying programs to solve problems (Fessakis et al., 2013). The roles of children in using technologies can correspond to the tutor/tool/tutee framework proposed by Taylor (1980). This framework provides an important foundation to classify all educational computing when researchers consider the roles of technologies in education. When children receive instruction like consumers, technologies are employed as tutors for their learning. Most of the technologies adopted in the reviewed studies played this role. For example, a computer game was designed to teach children about light and shadow (Hsu et al., 2011) or e-books were implemented to promote children's literacy (e.g., Korat, 2010). When children become creators of learning, the technologies can be either used as tools or tutees. For example, tablet PCs, digital cameras or recorders, and computer programs are all tools for children to express and communicate their ideas or to engage in social interactions with family members. With the increasing availability of various technologies at home and in schools, there would be a great opportunity for promoting children's learning by using these technology tools. On the other hand, the Logo-based programing environments, the Ladybug leaf and the Ladybug maze, adopted by Fessakis and his colleagues (2013) demonstrated an example of using technology as tutees. Children can modify the program or create new programs to lead the ladybug (the character in the software) through a leaf. Scholars have suggested that by using technology as tutees, learners could learn in more depth, learn more about the learning process, and link their experience to the fundamental concepts of learning subjects (c.f., Taylor, 1980).

Implications

Several implications for future research are proposed. The typology proposed in this study is expected to contribute to both research and practice. Following this typology, different factors influencing the results of technology-supported learning in young children can be systematically investigated and discussed. On the one hand, with more studies examining the children, adults, and technology factors, this typology can be validated further. The typology can also help educators and technology designers to consider the factors related to the learning outcomes. How to apply this typology to design or evaluate a technology-supported instruction or system will need to be discussed in the future. Another emerging concern of this reviewed topic is the roles of children as consumers or creators of technologies. How technologies can support young children to become creators will rely on future design of technologies and evaluation of their implementation. Moreover, how different types of technology can facilitate various developmental domains of children will need future exploration. It should be noted that although 13 studies provided the learning theories or teaching strategies they adopted to design the technologies, most of the reviewed articles did not explicitly state the learning theories underlying their studies. More studies framed on the basis of established learning theories are needed. Additionally, the learning results in this study were roughly classified to positive, negative, no difference, and "depends." To examine the learning effectiveness more precisely, a statistical meta-analysis is suggested to examine the degree of effectiveness of the learning results. Lastly, how different types of measures may influence the results of learning outcomes will need further investigation.

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