

Towards a knowledge base for using ict to foster early literacy development: A review study

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ABSTRACT

A review study was conducted to describe the knowledge and skills teachers need for designing, organizing, and adapting technology-rich learning environments for fostering early literacy development in the kindergarten classroom. The sample consisted of 46 articles that reported on the affordances of technology in relation to kindergartners' early literacy development. The review included studies on electronic books, computer-based training programs, technology-based curriculum supplements, technology-rich literacy curricula, assistive technology, and other educational media and sources for technology-rich literacy education. The findings report on the effects of technology and ict-applications on (aspects of) children's early literacy development including emergent reading and writing skills. The conclusions and discussion section focuses on the kind of evidence these studies provide in light of teachers' knowledge base for using technology and ict in early literacy education.

INTRODUCTION

Research on ict applications for early literacy shows that technology contributes to children's early literacy development, provided that it is used in an adequate way (Chambers et al., 2008; Klein et al., 2000; McKenney & Voogt, 2009; Savage et al., 2010). For example, Segers and Verhoeven (2005) found that kindergartners' phonemic awareness is enhanced by playing computer games of Treasure Chest for 15 minutes per week and Verhallen et al. (2006) showed that the use of electronic books and multimedia in the context of story telling fosters children's story comprehension. Furthermore, studies on the integration of technology-rich learning environments in early childhood education, such as the PictoPal learning environment with a particular focus on the functions of print, have promising results with regard to early literacy skill attainments (Cviko et al., 2012).

For many teachers, however, the integration of technology in the daily practice of teaching is a complex and challenging task, because they are often not able to use technology to its full potential (Labbo et al., 2003; Law, Pelgrum, & Plomp, 2008; Mumtaz, 2000). The success of technology use in the practice of teaching is determined by several factors, such as the presence or absence of facilitating conditions (Davidson, 2009), design characteristics of the tool (Nikolopoulou, 2007; Calvert et al., 2005), the user interface (Brabham et al., 2006), content of the software (Bronkhorst et al., 2009; Korat & Shamir, 2008; Schmidt et al., 2009), curriculum compatibility (Cassady & Smith, 2003; Bauserman et al., 2005), teacher competence (Mishra &

Koehler, 2006), teacher attitudes towards technology use in educational practice (Christensen & Knezek, 2008; Judge, 2005; Teo, 2010), and learner characteristics such as socioeconomic status (Korat & Shamir, 2008) and dyslexia (Lyytinen et al., 2007). As a consequence, it is difficult to replicate the findings from isolated experiments in classroom practice (Lankshear & Knobel, 2003; Olson, 2000).

From all of the factors mentioned above, teacher competence is identified as a key success factor for integrating technology and ict applications in the practice of teaching (Mishra & Koehler, 2006; Labbo et al., 2003; Labbo et al., 1995). Teachers' knowledge of the affordances of particular ict applications for early literacy development is often limited and they possibly lack particular skills needed for designing and organizing technology-rich learning environments (cf. Ertmer & Ottenbreit-Leftwich, 2010; Hew & Brush, 2007; Mumtaz, 2000). The purpose of this study is to describe the knowledge base of using technology and ict to foster early literacy development in early childhood education by conducting a review study of the literature in this field of interest.

THEORETICAL FRAMEWORK

The knowledge base of teaching

Professional teacher behavior is characterized by an interaction between teaching behavior, on the one hand, and teacher knowledge and beliefs, on the other (Belo, 2013; Calderhead, 1996; Verloop et al., 2001). In this respect, a key feature of teacher professionalism is a teacher's *knowledge base of teaching*. Verloop and colleagues (2001) define this knowledge base as "all profession-related insights that are potentially relevant to the teacher's activities" (p. 443). Thus, a teacher's knowledge base includes not only formal theoretical knowledge, which is derived from scientific research on teaching and learning, but also practical knowledge, such as beliefs, experiential knowledge, and practical arguments that influence day-to-day teaching activities and routines (cf. Meijer & Van Driel, 1999; Richardson, 1996; Shulman, 1986; Schön, 1983).

Composition of the knowledge base for using ict to foster early literacy development

In order to describe the knowledge teachers need to design, organize, and adapt technology-rich learning environments for fostering early literacy development in the kindergarten classroom, it is useful to realize that this knowledge base comprises 1) different *domains of knowledge* and 2) different *kinds of evidence*.

First, in line with the TPACK framework of Koehler and Mishra (2005), the knowledge base for using ICT to foster early literacy development mainly consists of three knowledge domains, namely *technological knowledge* (TK), *pedagogical knowledge* (PK), and *content knowledge* (CK). Technological knowledge (TK) refers to knowledge about the functions and affordances of technology and ict applications for teaching and learning, as well as knowledge about how to use technology and ict applications in such a way that it enhances student learning (Voogt, 2012; Jaipal & Figg, 2010). Pedagogical knowledge (PK) refers to knowledge about developmentally appropriate practices (cf. NAEYC, 2009) and includes knowledge about children's development and learning, formulation and assessment of appropriate learning goals, aspects of classroom management, and a child-centered pedagogy (focused on key principles such as building a supportive teacher-child relationships and fostering children's competence and autonomy by a challenging and safe learning environment) (cf. Model of Adaptive Teaching in Bosch & Boomsma, 2013, p. 290). Content knowledge (CK) refers to knowledge about the four main domains of early literacy development, namely reading, writing, listening, and speaking (Neuman & Dickinson, 2001; Dickinson & Neuman, 2006), and comprises knowledge about the different aspects of early literacy development (e.g., phonological and phonemic awareness, text comprehension, vocabulary, alphabet principle, concept about print, and so on) (cf. Whitehurst & Lonigan, 2001). The interplay between these three knowledge domains (TCK, TPK, and PCK) is especially important in determining the affordances of technology and ict for early literacy

development in early childhood education (cf. Koehler & Mishra, 2009; NAEYC & IRA, 2009; NAEYC & the Fred Rogers Center, 2012).

Second, the knowledge base for teaching comprises different kinds of evidence. According to Thomas (2004), a rough distinction could be made between evidence from teachers' personal or professional experience (e.g., personal success experiences, testimonies, evidence from archives or documents, observations, and so on) and evidence from educational research (e.g., idiographic research, nomothetic research with a poor design, randomized controlled trials, and so on). A key feature of teacher professionalism is deliberate and evidence-informed practice, characterized by thoughtful professionals that consciously reflect on the relevance of teaching specific content as well as the characteristics of appropriate instructional strategies in this respect (Belo, 2013; Loughran, 2010; Staub et al., 2003). Such professionals are able to accumulate different kinds of evidence from their knowledge base and to translate these into personal heuristics and rules of thumb for teaching (cf. Cordingley, 2004; Thomas, 2004).

FOCUS OF THE STUDY AND RESEARCH QUESTIONS

As mentioned, this review study aims at describing the knowledge base for using technology and ict to foster early literacy development in early childhood education (i.e., kindergarten classrooms) with a particular focus on evidence from educational research. More specifically, we aim at gaining insight in the content and focus of scientific studies that were conducted in the field as well as the type of evidence that these studies provide. The study is guided by the following research questions:

1. What is the content and focus of studies on technology and ict applications in relation to early literacy development?
2. What kinds of evidence do these studies provide about the affordances of technology and ict for fostering early literacy development?

METHODOLOGY

The purpose of the study was to conduct a comprehensive review of the literature about using technology and/or ict to foster early literacy development in early childhood education. Two reviews were used as a point of departure for defining the search and selection procedures, namely Lankshear and Knobel's (2003) review on new technologies in early childhood literacy research and the review of Plowman and Stephen (2003) on ict and pre-school children.

Search procedures

In June 2012 we searched articles in four databases, namely Scopus, Web of Science, ERIC, and PSYCinfo, by using the following search strategy and key words: (computer* OR technolog* OR ict OR media) AND (literacy OR early literacy OR emergent literacy). This resulted in 13,070 hits. A refinement for English language resulted in 12,524 hits, of which 3,681 were published from 1994 to 2002 and 4,763 was published after 2002. Further refinements with the keywords (kindergarten OR preschool) resulted in 253 hits; 41 were published from 1994 to 2000, 61 from 2000 to 2006, and 120 after 2006.

Selection procedures

Selection procedures focused on the relevance of an article as well as the year of publication. First, we judged an article to be relevant if it explicitly mentioned the affordances of technology or ict (e.g., instructional, educational or assistive) in relation to young children's early literacy development. For example, investigations of computer assisted instruction to foster phonological awareness or computer programs to train vocabulary, electronic books with particular characteristics to increase text comprehension or concept about print, technology-based or media-rich literacy curricula, and so on. The criteria that were used for inclusion

focused on a) *the role of technology, ict and/or media in the study* (i.e., it must be treated as an independent variable), b) *children's age* (i.e., the study should focus on pre-school and/or kindergarten settings, implying that the children of interest were on average 4 to 7 years old), c) *the purposes of technology, ict and/or media* (i.e. it should be designed and applied for educational purposes), and d) *the relation with (aspects of) early literacy development* (i.e., there should be an explicit relation to aspects of early literacy development). We decided not to include the criteria of teachers' active engagement, because several studies (e.g., investigations of the effects of electronic books on early literacy development) focus particularly on the independent practice of students. These studies, however, might include knowledge about the affordances of technology, ict and/or media that constitutes teachers' competence for designing and organizing technology-rich learning environments for fostering early literacy development. After reading the titles and abstracts of the 253 hits, 190 articles were selected for a thorough reading of the full text based on these inclusion criteria.

Second, with regard to the year of publication, we decided to exclude articles published before 2001. The reason is that the two reviews that were taken as a point of departure for this study, namely the review of Lankshear and Knobel (2003) and Plowman and Stephen's (2003) review, comprise an overview of relevant articles from approximately 1996 to 2002. Thus, together they present a picture of the state-of-the-art knowledge base of ict, early literacy, and early childhood at the beginning of the 21st century. The exclusion of articles published before 2001 resulted in 148 articles; 29 articles were in full text not online available and were consequently excluded from further investigation. After a thorough reading of the content of the remaining 119 articles, 46 articles were eventually selected based on the inclusion criteria mentioned above. Thus, the final sample included 46 studies that reported on the affordances of technology and/or ict in relation to early literacy development in early childhood education; these studies were published from 2001 to June 2012.

Content analysis procedures

The analysis consisted of two main phases. First, each of the 46 studies was analyzed by filling out a form containing the following six categories (cf. Edyburn, 2000): 1) *focus of the study* (e.g., electronic book, computer-based training program, technology-based literacy curriculum, assistive technology, and so on), 2) *purpose of the study* (e.g., evaluation of effects, exploration of interaction patterns, description of best practices with particular ict-applications, and so on), 3) *research design* (e.g., randomized controlled trial, quasi-experimental study, review, case study, design research, and so on), 4) if applicable, *characteristics of the intervention* (e.g., physical setting, facilitating conditions, information about number of sessions and time per session, and so on), 5) *sample characteristics* (large-scale or small-scale, learner characteristics such as age, SES, communication disorders, and so on), and 6) *outcomes of the study* related to early literacy development (e.g., statistical information such as effect sizes, identified barriers, design principles, and so on). Second, studies with the same focus were brought together and analyzed for patterns in the evidence.

RESULTS

Focus and research design of the studies under review

The final sample of 46 articles comprised 17 randomized controlled trials, 13 quasi-experimental studies, 5 case studies, 2 design studies, 1 grounded theory study, 1 ethnographic study, 2 reviews, and 5 best practices. With regard to the focus of the studies, 11 of the 46 studies focused on electronic storybooks, another 11 studies focused on computer-based training programs (related to one or more aspects of early literacy), and again 11 studies focused on technology-based, technology-rich, and/or media-rich curriculum supplements. The remaining studies focused on technology-based, computer-assisted, and/or media-rich curricula (5 studies), assistive technology (4 studies), and educational websites, television programs, and other resources (4 studies). Table 1 presents an overview of these studies.

Table 1. Overview of the studies included in the literature review with a categorization based on the focus of the study and research design

	RCT ^a	QES	CASE	DESIGN	GT	ETHNO	REV	BP	Total
Electronic storybook	7	2	2						11
Computer-based training program	6	5							11
Technology-based, technology-rich, and/or media-rich curriculum supplement (including computer-assisted instruction)	3	2	2	2			1	1	11
Technology-based, computer-assisted, and/or media-rich literacy curriculum	1	2						2	5
Assistive technology		1	1		1		1		4
Educational websites, television program, and other resources		1				1		2	4
Total	17	13	5	2	1	1	2	5	46

^aRCT = Randomized Controlled Trial; QES = Quasi-Experimental Study; CASE = Case study; DESIGN = Design research; ETHNO = Ethnographic study; REV=Review; BP = Best Practice.

As is shown in Table 1, the following six categories could be identified in the studies under review (based on the focus of the study): 1) electronic storybooks, 2) computer-based training programs, 3) technology-based, technology-rich, and/or media-rich curriculum supplements, 4) technology-based, computer-assisted, and/or media-rich literacy curriculum, 5) assistive technology, and 6) educational websites, television programs, and other resources.

Electronic storybooks refer to software with a primary focus on the reading of stories, often with built-in opportunities to interact with screen elements (e.g., hotspots and animated pictures). *Computer-based training programs* refer to ict applications that aim at training and gaining particular early literacy skills (e.g., blending, segmenting) or providing (extra) instruction in relation to particular aspects of early literacy development (e.g., vocabulary). Computer-based training programs could be used as a replacement of teacher-led instruction. *Technology-based, computer-assisted, and/or media-rich curriculum supplements* refer to ict applications that are primarily designed to supplement an existing literacy curriculum, for example by providing extra opportunities for processing particular content or gaining and applying specific early literacy skills. *Technology-based, computer-assisted, and/or media-rich literacy curricula* refer to existing curricula, in which technology and computer activities are part of the literacy program. *Assistive technology* refers to technology that is used to enhance communication and interaction (e.g., speech generating devices). Finally, *educational websites, television programs, and other resources* refer to media and other technological support systems that are used in the context of literacy education to foster (aspects) of early literacy development.

Affordances of technology and ict for early literacy development

For each of the 46 studies, an overview of the information about author(s), purpose of the study, research design, characteristics of the intervention (if applicable), sample characteristics, and outcomes of the study (including effect sizes) is provided in the Appendix. In the following paragraphs we summarize the main findings by combining the evidence of the various studies.

Electronic storybooks (11 studies)

Studies on electronic books (e-books) show that reading e-books could have a significant effect on early literacy development. This is especially true for 'story understanding' (Verhallen et al., 2006; De Jong & Bus, 2004), 'receptive and expressive vocabulary' (Verhallen et al., 2010; Verhallen et al., 2006), 'word meaning' (Korat & Blau, 2010; Korat, 2010; Korat & Shamir, 2008), 'word recognition' (Korat & Blau, 2010; Korat, 2010; Korat & Shamir, 2008), 'phonological awareness' (Korat et al., 2009; Segal-Drori et al., 2010; Shamir et al., 2008), 'emergent reading skills' (Korat et al., 2009; Segal-Drori et al., 2010; Shamir et al., 2008), 'syntax' (Verhallen et al., 2006), and 'concept about print' (Segal-Drori et al., 2010). Furthermore, these studies are mainly characterized by an investigation of 1) the effects of e-books on (aspects of) early literacy development *compared to printed books*, 2) the effects of different *interface design characteristics* of e-books, 3) the effects of different *e-book reading circumstances*, and 4) *patterns of interaction* while reading e-books.

First, the three studies that compared the effects of children's independent use of e-books with reading printed books aloud (by adults) showed no clear differences between using e-books and printed books (Segal-Drori et al., 2010; Korat et al., 2009; De Jong & Bus, 2004). Both the use of e-books and printed books resulted in significant early literacy learning gains. Second, the three studies on interface design characteristics were characterized by an exploration of the effects of different activity modes (Korat & Shamir, 2008) and a comparison of static images versus multimedia or video images (Verhallen et al., 2010; Verhallen et al., 2006). These studies showed that in particular the activity mode 'read story with dictionary' contributed to 'word meaning' and 'word recognition'. Moreover, the effects of using multimedia and video images were larger for 'expressive vocabulary', 'recall of implied story elements', and 'syntax' compared to using static images. Third, the studies on different e-book reading circumstances were characterized by a comparison of a) the number of encounters with the story, such as five times versus three times (Korat & Blau, 2010) and four times versus once (Verhallen et al., 2006), b) adult instruction versus no instruction (Segal-Drori et al., 2010) and adult support versus no support (Korat et al., 2009), and c) paired peer use versus individual use (Shamir et al., 2008). These studies showed that an increasing number of encounters with the story often resulted in larger learning gains in 'story understanding', 'vocabulary', 'syntax', and 'word reading' (Korat & Blau, 2010; Verhallen et al., 2006). In addition, adult instruction and adult support while reading e-books (and printed books) resulted often in significant larger improvement scores of 'phonological awareness', 'emergent word reading', and 'concept about print' compared to no instruction and support. The study of Shamir et al. (2008) showed that children who used the e-book in tutor-tutee pairs scored higher on 'phonological awareness' (sub-syllabic awareness) and 'emergent reading' compared to individual users of e-books. This was especially true for children in the role of tutor. Fourth and finally, the two studies on patterns of interaction while reading e-books focused on children's interaction with augmented storybooks (Hornecker & Dünser, 2009) and parent-child interaction patterns while reading storybooks with choice points (Fisch et al., 2002). Hornecker and Dünser (2009) found that most children are able to interact independently with the e-book after some initial help. In this respect, children's interaction with on-screen elements is mainly characterized by intuitive use. With regard to natural parent-child interaction patterns, it was observed that most parents ask their child questions in an attempt to make a connection between the story content and a child's personal life experiences.

Computer-based training programs (11 studies)

Seven of the eleven studies on computer-based training programs focused on software titles that were specialized in teaching one specific aspect of early literacy, namely *phonics/letter-sounds* (Savage et al., 2009; Comaskey et al., 2009; Kegel et al., 2009; De Graaff et al., 2009; De Graaff et al., 2007; Brabham et al., 2006; Volpe et al., 2011). Besides that, two studies focused on a computer-based *vocabulary* training program (Segers et al., 2006; Segers & Verhoeven, 2005); and two studies investigated a computer-based training program that was characterized by a

broader focus on a *variety of emergent literacy skills*, such as whole word recognition, written word naming, and phonological awareness (Karemaker et al., 2010a; Karemaker et al., 2010b).

With regard to the training of phonics/letter-sounds, the following software titles were investigated: 'Living Letters' (Kegel et al., 2009), ABRACADABRA (Savage et al., 2009; Comaskey et al., 2009), 'Klankie' (De Graaff et al., 2009; De Graaff et al., 2007), 'Dr. Seuss's ABC – electronic Alphabet books' (Brabham et al., 2006), and "Tutoring Buddy" (Volpe et al., 2011). Most of these studies were characterized by an investigation of different phonics training methods, such as a) '*phoneme-based synthetic* phonics method' versus '*rime-based analytic* phonics method', b) '*emphasis on meanings of words*' versus '*emphasis on phonemes* represented by the letters', c) '*fading condition*' versus '*embedded condition*' versus '*without picture condition*', d) '*systematic* phonics training' versus '*unsystematic* phonics training', and e) '*incremental rehearsal procedure*'. These studies showed that a phoneme-based synthetic phonics method lead to significant higher scores in 'blending' (consonant-vowel, vowel-consonant), 'common unit coda', 'listening comprehension' and 'reading comprehension', whereas a rime-based analytic phonics method resulted in higher scores on 'letter-sound knowledge' and 'common unit rime articulation'. Furthermore, a training method with an emphasis on phonemes represented by the letters lead to significant greater learning gains in 'phoneme awareness' compared to a trainings method with an emphasis on meanings of words. With regard to 'productive letter-sound knowledge', a trainings method with a fading condition resulted in higher test scores. In this respect, the transition from 'vague picture' to 'no picture' turned out to be an important step in the learning process. A systematic trainings condition resulted in higher improvement scores on 'free sound isolation', 'reading', and 'spelling', and an incremental rehearsal procedure showed promising results with regard to teaching letter-sounds to children that were identified at risk for reading failure. Besides these effects on early literacy development, the investigation of the 'Living Letters' computer program showed that children with poor regulation skills have significant more problematic computer-behavior compared to those with average or high regulation skills (Kegel et al., 2009).

Segers and colleagues investigated in two studies (2005, 2006) the vocabulary-training program 'Treasure Chest with the Mouse'. Significant intervention effects were found for 'vocabulary' development, in particular with respect to experimental words (compared to control words). Moreover, they found significant correlations between the time spent on particular games and learning gains in emergent literacy skills. Negative correlations were found between *discovery games* and learning gains in 'rhyming', 'phonemic segmentation', 'auditory blending' and 'grapheme knowledge', whereas positive correlations were found between *learning games* (with a focus on rhyme and blending) and learning gains in 'rhyming'. In addition, *games involving letters* were positively correlated to learning gains in 'phonemic segmentation', 'auditory blending', and 'grapheme knowledge'. No differences were found in task-on behavior between the experimental and the control group.

Finally, Karemaker et al. (2010a, 2010b) investigated the multimedia software program 'ORT for Clicker'. They found that the use of the computer program resulted in larger improvement scores in 'segmentation' and 'written word recognition' compared to the control group (that used traditional Big Books).

Technology-based, technology-rich, and/or media-rich curriculum supplements (11 studies)

With regard to the studies on technology-based, technology-rich, and/or media-rich curriculum supplements a rough distinction can be made between 1) software titles that are designed primarily in relation to the *early literacy curriculum*, 2) software that is designed for *tutorial activities*, and 3) other types of software (including commercial educational software).

First, a distinction can be made between curriculum supplements with a primary focus on *early reading and writing skills development* and supplements focusing on *functions of print*. Four studies focused on curriculum supplements with a specific focus on teaching emergent reading and writing skills (Penuel et al., 2012; Macaruso & Rodman, 2011; Macaruso & Walker, 2008; Torgesen et al., 2010). Overall, these studies showed that frequently use of such computer assisted curriculum supplements often results in significant learning gains in 'letter-sound

awareness', 'letter name knowledge', 'story and print concepts' (Penuel et al., 2012), 'phonological awareness', and 'sound matching' (Macaruso & Rodman, 2011; Macaruso & Walker, 2008). However, Torgesen et al. (2010) compared the 'Read, Write, and Type' (RWT) curriculum supplement with both the 'Lindamood Phoneme Sequencing Program for Reading Spelling and Speech (LIPS) computer program and a control group. They found no significant differences between the experimental groups and control group.

Furthermore, three studies focused on PictoPal, a technology based literacy curriculum supplement with a particular focus on functions of print (Cviko et al., 2012; McKenney & Voogt, 2009; Voogt & McKenney, 2007). McKenney and Voogt (2007; 2009) found that the *number of sessions* with PictoPal was an important variable. After four sessions, no significant differences were found between the experimental and the control group, however after eight sessions children in the experimental group scored significant higher on the early literacy skills test. These findings are in line with the study of Cviko et al. (2012). The effects of PictoPal were also influenced by variables such as *children's age* (junior kindergartners had significant higher improvement scores than senior kindergartners, senior kindergartners showed higher engagement with the computer activities than junior kindergartners), *children's technical skills* (during the first sessions, children need some initial support and guidance to develop specific technical skills such as mouse control behaviour), the *nature of the assignments* (semi-open assignments with real-world applications are more interesting, engaging, and authentic), the level of *integration of on- and off-computer activities* (teachers need to work several times with PictoPal before they are skilled in linking on-computer activities to both off-computer activities and early literacy curriculum goals, high integration of on- and off-computer activities probably results in higher learning gains), and *teachers' perceptions of technology-based education* (differences were found in perceptions of teaching and learning, attitudes towards computers, and attitudes towards technology-based innovations).

Second, two studies investigated software designed for tutorial activities. Bauserman et al. (2005) studied PLATO's Integrated Learning System (ILS), a tutorial reading curriculum supplement. They found that children in the intervention group had significantly higher scores on 'phonological awareness', 'knowledge about print concepts', and 'listening comprehension'. Schmidt and colleagues (2008) investigated the use of an Electronic Performance Support System (EPSS) during tutorial sessions. They found that the tutor played a crucial role in animating the session and keeping pupils motivated. Although the EPSS contained an automatically reward system, all tutors used rewards (e.g., movies) throughout the session to enhance children's engagement or when they felt the need to do so. Moreover, the rapport between tutor and child, often created by chitchatting and off-task interactions, was an essential element of creating learning opportunities (e.g., activating background knowledge, connecting to a child's personal experiences, and so on). The study showed that both the interface design of the technology and the guiding role of the tutor was important, especially when children were confronted with difficult tasks.

Third, Santoro and Bishop (2010) conducted a review on (commercial) instructional technology software titles and found that most titles in the sample did not meet the evaluation criteria of interface design, instructional design, and criteria related to the content (e.g., phonological awareness and alphabetic understanding). In addition, most software was designed with a specific focus on either 'phonological awareness' or 'alphabetic understanding' instead of including computer activities related to both literacy aspects. The study of Parette et al. (2008) included examples of how to use the word and symbol processing software program 'Writing with Symbols 2000' (WWS 2000) to foster early literacy development. They especially focused on the added value of the program for fostering children's 'concepts about print', 'phonemic awareness', 'alphabetic principle', 'vocabulary development', and 'comprehension'.

Technology-based, computer-assisted, and/or media-rich literacy curricula (5 studies)

Three different technology-based literacy curricula were investigated, namely the *Waterford Early Reading Program (WERP)* (Johnson, 2010; Tracey & Young, 2007; Powers & Price-Johnson,

2007), the *'Ready, Set, Leap!'* (RSL) technology-based literacy curriculum (Davidson, 2009), and the *LitTECH Outreach* technology-based preschool literacy project (Johanson et al., 2008).

With reference to the WERP curriculum, no clear evidence is provided that the experimental curriculum has a significant greater effect on children's early literacy development compared to a control group. One study investigated the effects of different presentation modes of the WERP curriculum, namely a *learner-controlled picture menu* versus a *linear sequencer* versus a *mastery-based adaptive sequencer* (Johnson, 2010). This study showed that children in the linear sequencer group had significantly higher scores on 'initial sound fluency' compared to the control group, whereas children in the mastery-based adaptive sequencer had significantly higher scores on 'nonsense word fluency' compared to the control group. Overall, no significant differences were found in the effects of the linear and mastery-based adaptive sequencer modes.

Furthermore, studies on the effects of the RSL and the LitTECH Outreach technology-based curricula reported no convincing evidence that children in the experimental groups had significant higher early literacy learning gains compared to children in a control group. In this respect, Davidson et al. (2009) reported that high-fidelity classrooms of the RSL curriculum had significant higher scores on 'word blending' and 'rhyming' compared to low-fidelity classrooms.

Assistive technology (4 studies)

The four studies on assistive technology included a review of the literature about *barriers in the use of assistive technology* (Floyd et al., 2008), a study of the *affordances of high- and low-assistive technologies* for the literacy development of children with disabilities (Beck et al., 2002), a study of the effects of *differences in display of a speech-generating device* (Jackson et al., 2011), and an investigation of *multimedia physical storytelling technology* called 'StoryRooms' (Guha et al., 2007).

The review of Floyd and colleagues (2008) showed that *teachers' perceptions, attitudes, and practices* are the biggest barrier in using assistive technology. Teachers need training and support to integrate this technology in their everyday teaching practices. Other barriers were more related to *socio-cultural issues* and *practical considerations* instead of the assistive technology itself. Beck et al., (2002) found that both high- and low-assistive technologies provided opportunities to foster children's literacy development. They illustrated their claim by giving examples of using *picture communication symbols, adapted books*, and software titles such as *Intellikeys* and *Intellipics* in the context of literacy education. Jackson et al. (2011) studied the effects of differences in overlay design (i.e., a *visual scene display* to a *grid display*) of a speech-generating device in the context of interactive storybook reading. They found that children did not often spontaneously activate the speech-generating device while an adult read the story, no matter what overlay design was used. However, when children got access to the speech-generating device during free play and exploration in advance of the interactive reading sessions, the number of spontaneous activations increased significantly. No significant differences were found in the effects of the different types of overlay design and the way children responded to open-ended and closed-ended questions. The study of Guha et al. (2007) focused on what variables should be considered when multimedia physical storytelling technology is used to enrich children's storytelling. They found that the appropriate degree of control over the technology is determined by both child-related and context-related variables (e.g., child: cognitive development, social development, background; context: physical setting, distraction, support by adults and peers).

Educational websites, television program, and other resources (4 studies)

The remaining four studies focused on educational websites, television episodes, and other online resources. First, with regard to *educational websites* (Thurlow, 2009), it was concluded that the usefulness of educational websites could be evaluated by focusing on *usability issues* (e.g., internet safety, internet navigation, internet advertisements) and to what extent *early literacy skill development* is fostered. In this respect, it was difficult to find websites that are accessible and engaging for children and, at the same time, can be judged educational.

Second, two studies investigated educational television episodes (Jennings et al., 2009; Linebarger & Piotrowski, 2009). Linebarger and Piotrowski (2009) compared different viewing conditions, namely *expository viewing* versus *embedded narrative viewing* versus *traditional narrative viewing*. They found that children in the narrative viewing conditions (both embedded and traditional) had significantly higher scores on 'story knowledge' than children in the other conditions. Moreover, children in the embedded narrative viewing condition had significantly higher scores on 'narrative retelling' and 'narrative comprehension' than children in the traditional narrative condition. Jennings et al. (2009) investigated both children's engagement with television episodes and how early literacy is addressed in these television programs. They found that most educational television episodes pay attention to early literacy development by reading stories and showing animations combined with songs. In addition, they recommended the use of different educational materials in early literacy education, because children did not make a clear distinction between knowledge derived from different media.

Finally, one study investigated the content of an online resource system related to early literacy education, namely the interactive web-based system 'Interactive Technology Literacy Curriculum, ITLC Online' (Robinson et al., 2006). This study reported that the resource system included *recommendations to use specific software titles, classroom management techniques* to integrate literacy activities in group activities and free time, *information about critical classroom management factors* (e.g., the location of the computer center, facilitating children's management of the computer center, support of computer users to promote communication and social skills, and so on), and *examples of language-rich learning environments* that enable children to be actively involved in language development.

CONCLUSIONS AND DISCUSSION

Research evidence about affordances of technology and ict for early literacy development

The purpose of this literature review study was to describe the research evidence for using technology and ict applications to foster early literacy development in early childhood education. With regard to the content and focus of studies on technology and ict applications in relation to early literacy development (research question 1), we conclude that about 25 percent of the studies (11 out of 46) in this review focused on e-books and another 25 percent (11 out of 46) on computer-based training programs (most of these ict applications focus on teaching phonics). These studies provide evidence mainly derived from randomized controlled trials and quasi-experimental studies. The other half of the studies under review focused on technology-based literacy curriculum supplements (11 out of 46), technology-based literacy curricula (5 out of 46), assistive technology (4 out of 46), and other media and online resources (4 out of 46). The evidence that these studies provide are derived from both quantitative and qualitative studies.

With regard to the kinds of evidence about the affordances of technology and ict applications for fostering early literacy development (research question 2), it is not easy to draw firm conclusions. We started the study with the observation that many teachers struggle with integrating technology into their daily teaching practice, partly caused by the fact that their knowledge about the affordances of technology and ict for early literacy development is limited and that they lack skills needed for designing and organizing technology-rich learning environments. Most of the studies that we reviewed share a primary focus on main effects of a specific technology/ict-application on children's literacy development. In these studies, we observed a trend that the authors often do not pay much attention to the teachers' role, for instance they rarely formulate guidelines and criteria for effective technology integration in early childhood literacy education (e.g., effective instructional and classroom management strategies in relation to the specific technology) or say nothing about what off-computer activities should be linked to on-computer activities, and so on. This is especially true for the studies containing randomized controlled trials and quasi-experimental studies. Thus, although strong evidence is found for the effects of such technology on children's early literacy

development, replication of these findings is not guaranteed due to a lack of suggestions about how to translate these 'laboratory' circumstances to the complex context of early childhood education. In contrast, the descriptive studies with for example a case study method, grounded theory method, and ethnographic method were more informative about implications for integrating technology and ict in the practice of teaching. This was especially true for the three design research studies on the PictoPal curriculum that explicitly included research questions about the role of the teacher and aspects of technology-integration (Cviko et al., 2012; McKenney & Voogt, 2009; Voogt & McKenney, 2007). However, again the replication of significant effects found could be questioned because the findings of these studies are often very context-specific (e.g., influenced by teacher characteristics or particular teaching behavior).

Research evidence as part of the knowledge base for technology-rich education

As mentioned in the introduction and theoretical framework of this paper, one of the key success factors for designing and organizing technology-rich learning environment is a teacher's competence to integrate technology and ict applications into the practice of teaching in such a way that the technology has an added value for learning. This teacher competence is manifested in at least the following two professional behaviors (cf. Hutinger et al., 2005): First, teachers make judgments about the affordances of technology and ict for children's early literacy development by using knowledge from different domains (cf. the TPACK framework described by Koehler & Mishra (2009) and Voogt (2012)). Moreover, the trustworthiness, value, and applicability of different kinds of evidence, both derived from educational research and from the practice of teaching, should be evaluated. In other words, the teacher competence manifests itself not only in having and building a personal knowledge base for technology-rich education, but also in professional reasoning, that is anchored to this knowledge base (cf. Verloop et al., 2001). Second, teachers should be able to translate their insights about the affordances of specific technology and ict-applications for early literacy education into personal heuristics, instructional strategies, and design principles for technology-rich learning environments.

Various scholars have pointed at the crucial role of training and professional development in order to acquire this competence (e.g., Davidson et al., 2009; Judge, 2005; Robinson et al., 2006). In this respect, the question arises what such a training should focus on. According to Hutinger et al. (2005), a curriculum integration training has more impact on the integration of technology in teachers' early literacy education than a training in basic software skills (cf. Ihmeideh, 2009). A curriculum integration training could focus on aspects, such as becoming comfortable with the technology (cf. Cviko et al., 2012), the ability to troubleshoot, making technology accessible to children, allowing children to make choices about software, fostering and facilitating peer interaction while conducting on-computer activities (cf. Hutinger et al., 2005; Mitchell & Dunbar, 2006), and so on. Moreover, such a training should be anchored to knowledge about important early literacy development aspects, critical classroom management factors, and research evidence about the affordances of technology and ict applications for children's early literacy development (cf. Robinson et al., 2006). In this respect, more research is needed about what constitutes the process of integrating and 'fitting' research evidence into a teacher's personal knowledge base of teaching, as well as what characterizes a teacher's learning process in making this knowledge accessible for designing, organizing, and adapting technology-rich learning environments to foster children's early literacy development.

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