Teacher knowledge for using technology to foster early literacy:
A literature review

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Abstract

A literature review was conducted to describe the knowledge and skills teachers need for using technology to foster early literacy development in kindergarten classrooms. The study was guided by three research questions, concerning 1) effects of specific technologies, 2) effective design characteristics and 3) effective use of such applications. 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-rich literacy curricula, assistive technology, and other educational media and sources for technology-rich literacy education. The following software applications were found effective in fostering kindergartners’ early literacy development: Electronic storybooks, computer-based phonics and vocabulary training programs, software applications that enable children to ‘read and write’, software applications that are designed for tutorial activities, and educational television programs with a narrative format. Few of the studies reviewed provided specific information about effective design characteristics of such applications or concrete guidelines for using technology in developmentally appropriate fashion in kindergarten. Theoretical and practical implications are discussed.

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1. 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, Nir-Gal, & Darom, 2000; McKenney & Voogt, 2009; Savage, Abrami, Hipps, & Deault, 2009). For example, Segers and Verhoeven (2005) found that kindergartners’ phonemic awareness is enhanced by playing computer games of Treasure Chest for 15 min per week and Verhallen, Bus, and Dejong (2006) showed that the use of electronic books and multimedia in the context of storytelling 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, McKenney, & Voogt, 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 (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur & Sendurur, 2012; Labbo et al., 2003; Webb & Cox, 2004). 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, Fields, & Yang, 2009), design characteristics of the tool (Nikolopoulou, 2007; Calvert, Strong, & Gallagher, 2005), the user interface (Brabham, Murray, & Bowden, 2006), content of the software (Bronkhorst, Verhoeven, Biemond, & Schouten, 2009; Korat & Shamir, 2008; curriculum compatibility (Cassady & Smith, 2003; Bauserman, Cassady, Smith, & Stroud, 2009), 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, Ronimus, Alanko, Poikkeus, & Taanila, 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, 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, organizing, and adapting technology-rich learning environments (cf. Ertmer & Ottenbreit-Leftwich, 2010; Hew & Brush, 2007; Mumtaz, 2000). The purpose of this study was to conduct a literature review in order to describe the knowledge that is important for making informed decisions about using ict to foster early literacy development in early childhood education.

2. Theoretical framework

2.1. TPACK: a model to frame the literature review

In order to describe the knowledge that is important in the process of designing, organizing, and adapting technology-rich learning environments for fostering early literacy development in early childhood education, it is useful to realize that different domains of knowledge are involved. In line with the TPACK framework of Koehler and Mishra (2005), we identify 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, Fisser, Pareja Roblin, Tondeur, & Van Braak, 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). This study does not focus on the domains in isolation, but rather explores those areas where content knowledge (CK) and pedagogical knowledge (PK) are connected to technology (TCK, TPK, and TPACK), because these are especially important in determining the affordances of technology for early literacy development in early childhood education (cf. Koehler & Mishra, 2009; NAEYC and IRA, 2009; NAEYC and the Fred Rogers Center, 2012).

2.2. The competence of using ict to foster early literacy development

Teachers who are competent in using ict to foster kindergartners' early literacy development possess, among other things, sufficient knowledge and skills 1) to select computer-based instructional materials that are effective in fostering early literacy development, 2) to determine whether the use of ict has an added value for teaching specific aspects of early literacy to particular students, and 3) to effectively integrate appropriate computer-based materials in their early childhood classrooms in order to create developmentally appropriate practices for early literacy learning (cf. Huizenga, Handelzalts, Nieveen, & Voogt, 2013; NAEYC, 2009; NAEYC and IRA, 2009; NAEYC and the Fred Rogers Center, 2012).

First, in order to select effective computer-based instructional materials teachers need to be knowledgeable about the effects of ict (i.e., particular software applications) on students' early literacy development and about effective design characteristics of such computer-based instructional materials. Second, in determining whether the use of ict has an added value for teaching specific aspects of early literacy to particular students, teachers need to know how ict should be used in order to create optimal learning opportunities for individual students. Third, the effective integration of ict into the daily practice of early childhood education implies that teachers are able to make deliberate and justified decisions about a) the appropriate role and content of ict in relation to the present early literacy curriculum, b) the roles of the teacher and the students during particular teaching and learning activities, c) the social organization of the classroom, and d) appropriate assessment practices (cf. Ertmer et al., 2012). Needless to say, teachers should be able to act accordingly.

The effective integration of technology-rich learning environments in kindergarten education is, besides these practical considerations, also affected by curriculum compatibility (Cassady & Smith, 2003; Bauserman et al., 2005). In other words, such learning environments should match with the targets of the existing early literacy curriculum in early childhood education. In general four strands can be distinguished in these targets, namely 1) book orientation and text comprehension, 2) phonics (i.e., phonological awareness and alphabetic principle), 3) functions of print and relations between spoken en written language, and 4) vocabulary development (cf. Verhoeven & Aarnoutse, 1999; Bronkhorst et al., 2009; McKenney, Bradley, & Boschman, 2011). Thus, the competence of using ict to foster early literacy development implies also that teachers are able to relate the selection and use of computer-based instructional materials to the targets of the early literacy curriculum.

3. Focus of the study and research questions

This review study aims at describing the knowledge that is important for helping teachers and teacher educators to make informed decisions about using ict to foster early literacy development in early childhood education.

The study is guided by three research questions, relating to TCK, TCK and PCK, and TPACK, respectively. The questions are:

1. What software applications are effective in fostering children's early literacy development?
2. What are the design characteristics of the software applications (mentioned under 1) that are effective in fostering children's early literacy development?
3. How should such software applications (mentioned under 1) be used in order to create optimal early literacy learning opportunities for individual children?

4. Methodology

The purpose of the present study was to conduct a comprehensive review of the educational literature about using 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 (2005) review on new technologies in early childhood literacy research and the review of Plowman and Stephen (2003) on ict and pre-school children.
4.1. 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 technology 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 3681 were published from 1994 to 2002 and 4763 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.

4.2. 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. We looked for original research as well as reviews of empirical and theoretical work that resulted in guidelines for use (third research question). The criteria that were used for inclusion focused on a) the ICT/media in the study were treated as an independent variable, b) the study should focus on early childhood classrooms (4–7 year-olds), c) ICT and/or media are designed and applied for educational purposes, and d) there should be an explicit relation to aspects of 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.

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 (2003) review, comprise an overview of relevant articles from approximately 1996 to 2002 and 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 published from 2001 to June 2012.

4.3. 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, 2) purpose of the study, 3) research design, 4) if applicable, characteristics of the intervention, 5) sample characteristics, and 6) outcomes of the study related to early literacy development.

Second, we categorized the 46 studies by relating the outcomes of each study to the four strands that were distinguished in the targets of the early literacy curriculum in kindergarten (cf. Verhoeven & Aarnoutse, 1999; Bronkhorst et al., 2009; McKenney et al., 2011), namely 1) book orientation and text comprehension, 2) phonics (i.e., phonemic and phonological awareness and alphabetic principle), 3) functions of print and relations between spoken and written language, and 4) vocabulary development. Furthermore, for each study we described effective design characteristics of the software application (e.g., interface, trainings procedures, etc.) and the extent the studies under review provided guidelines concerning the effective use of such software applications for fostering early literacy learning (e.g., suggestions about the role of the teacher and the students, social organization of the classroom, etc.). We discussed the results of the analyses in both phases in a team of three educational researchers until consensus was reached.

5. Results

Table 1 shows an overview of the 46 studies that were included in the final sample. Each of the studies is classified according to its main focus and research approach. The focal areas were: electronic storybooks; computer-based phonics and vocabulary training programs; other early literacy software applications; technology-based, computer-assisted, and/or media-rich literacy curricula; assistive technologies; and educational websites, television programs, and other resources. The research approaches included: randomized controlled trials; quasi-experimental studies; case studies; ethnographic studies; review studies and recommendations based on research synthesis (this last category refers to reviews of theoretical and empirical work that result in specific position statements about good practice).

5.1. Software applications that are effective in fostering kindergartners’ early literacy development based on empirical evidence (TCK)

5.1.1. Electronic storybooks

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). The studies on electronic books (e-books) showed that reading e-books could have a significant effect on children’s early literacy development. First, various studies showed that the use of electronic books had a significant effect on aspects of book orientation and text comprehension, such as story understanding (De Jong & Bus, 2004; Korat & Blau, 2010; Verhallen et al., 2006), recall of implied story elements (Verhallen et al., 2006; Verhallen & Bus, 2010), concept about print (Segal-Drori, Korat, Shamir, & Klein, 2010) and syntax (Verhallen et al., 2006). Second, four studies showed the effect of electronic books on phonics, namely on phonological awareness and emergent word reading skills (Korat & Blau, 2010; Korat, Segal-Drori, & Klien, 2009; Segal-Drori et al., 2010; Shamir, Korat, & Barbi, 2008). Third, no studies were found that showed significant effects of electronic storybooks on functions of print and relations between spoken and written language. Finally, three studies showed that using e-books had a significant effect on children’s vocabulary development (Korat & Shamir, 2008; Verhallen et al., 2006; Verhallen & Bus, 2010).

5.1.2. Computer-based phonics and vocabulary training programs

Computer-based phonics and vocabulary 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 phonics or vocabulary. Such training programs can be used as a replacement of teacher-led instruction. Three studies showed significant effects of computer-based phonics training programs on kindergartners’ book orientation and text comprehension (Savage et al., 2009; Comaskey, Savage, & Abrami, 2009; Penuel et al., 2012) and ten studies showed significant effects of such programs (e.g., Living Letters, ABRACADABRA, etc.) on phonics, that is on phonological awareness and alphabetic principle.
Table 1
Overview of the studies included in the literature review.

<table>
<thead>
<tr>
<th>Category</th>
<th>RCT</th>
<th>QES</th>
<th>CASE</th>
<th>ETHNO</th>
<th>REV</th>
<th>RbRS</th>
<th>Total</th>
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<td>2</td>
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<td>1</td>
<td></td>
<td>7</td>
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<td>9</td>
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<td>1</td>
<td></td>
<td></td>
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<td>7</td>
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<tr>
<td>Educational websites, television program, and other resources</td>
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<td>1</td>
<td>2</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
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<td>13</td>
<td>8</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>46</td>
</tr>
</tbody>
</table>

* RCT – Randomized Controlled Trial; QES – Quasi-Experimental Study; CASE – Case study; ETHNO – Ethnographic study; REV – Review; RbRS – Recommendations based on Research Synthesis.

(Brabham et al., 2006; Comaskey et al., 2009; De Graaff, Verhoeven, Bosman, & Hasselman, 2007; De Graaff, Bosman, Hasselman, & Verhoeven, 2009; Karemaker, Pitchford, & O’Malley, 2010a, 2010b; Macaruso & Rodman, 2011; Macaruso & Walker, 2008; Savage et al., 2009; Penelou et al., 2012). Furthermore, no significant effects of computer-based phonics and vocabulary training programs were found on functions of print and relations between spoken and written language. Finally, two studies showed that a computer-based vocabulary training program, namely Treasure Chest with the Mouse, significantly affected children’s vocabulary development (Segers, Nooijen, & De Moor, 2006; Segers & Verhoeven, 2005).

5.1.3. Other early literacy software applications

This category refers to software applications that provide, for example, extra opportunities for processing particular content or gaining and applying specific early literacy skills. The studies that investigated the effects of these software applications on children’s early literacy development were characterized by a focus on 1) software applications that enable children to ‘read and write’ and 2) software applications for tutorial activities.

First, four studies focused on software applications that enable children to ‘read and write’ by means of words and symbols. Three of the four 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). The latter two studies showed that after eight sessions children in the experimental group scored significantly higher on functions of print and relations between spoken and written language than the control group. These findings are in line with the study of Cviko et al. (2012). The study of Paarette, Boeckmann, and Hourcade (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. However, the suggested effect of this software program (WWS 2000) on children’s early literacy development was not supported by empirical evidence.

Second, two studies investigated software applications 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 book orientation and text comprehension and phonics compared to the control group. Schmid, Miodrag, and Di Francesco (2008) investigated the use of an Electronic Performance Support System (EPSS) during tutorial sessions. However, significant effects on children’s early literacy development were not reported.

5.1.4. Computer-based early literacy curricula

Computer-based early literacy curricula refer to existing curricula, in which technology and computer activities are an integral part of the literacy curriculum. Three different technology-based literacy curricula were investigated, namely the Waterford Early Reading Program (WERP) (Johnson, Perry, & Shamir, 2010; Tracey & Young, 2007; Powers & Price-Johnson, 2007), the ‘Ready, Set, Leap!’ (RSL) technology-based literacy curriculum (Davidson et al., 2009), and the LitTECH Outreach technology-based preschool literacy project (Johanson, Bell, & Daytner, 2008). The studies on the WERP curriculum showed no clear evidence that the experimental curriculum had a significant greater effect on children’s early literacy development compared to the control groups. Furthermore, the studies on the effects of the RSL and the LitTECH Outreach technology-based curricula reported also no convincing evidence that children in the experimental groups had significant higher early literacy learning gains compared to children in the control groups. However, Davidson et al. (2009) noticed that high-fidelity classrooms of the RSL curriculum had significant higher scores on ‘word blending’ and ‘rhyming’ compared to low-fidelity classrooms.

5.1.4.1. Assistive technology. Assistive technology refers to technology that is used to enhance communication and interaction (e.g., speech generating devices). The four studies on assistive technology included a review of the literature about barriers in the use of assistive technology (Floyd, Smith Cantor, Jeifis, & Judge, 2008), a study of the affordances of high- and low-assistive technologies for the literacy development of children with disabilities (Book et al., 2002), a study of the effects of differences in display of a speech-generating device (Jackson, Wahlquist, & Marquis, 2011), and an investigation of multimedia physical storytelling technology called ‘StoryRooms’ (Guha, Druin, Montemayor, Chipman, & Farber, 2007). These studies provided interesting insights concerning important barriers in using assistive technology in education (e.g., teachers’ attitudes towards using ICT in the context of education, a lack of training and support, socio-cultural issues, and practical considerations), opportunities to foster children’s literacy development by high- and low-assistive technologies (e.g., using picture communication symbols, adapted books, and software titles such as ‘Intellikeys’ and ‘Intellipics’), and what variables should be considered when multimedia physical storytelling technology is used to enrich children’s storytelling (e.g., child-related variables, such as cognitive and social development, and context-related variables, such as physical setting, distraction, and support by adults and peers). However, these studies did not clearly report significant effects of such technology on children’s early literacy development.

5.1.5. Educational websites, television programs, and other resources

The remaining four studies focused on educational websites, television programs, and other online resources. First, Thurlow (2009) evaluated educational websites by focusing on usability issues (e.g., internet safety, internet navigation, internet advertisements) and to
what extent early literacy skill development is fostered. He concluded that it was difficult to find websites that were accessible and engaging for children and, at the same time, could be judged educational. In addition, significant effects of such websites on children's early literacy development were not reported. Second, two studies investigated educational television programs (Jennings, Hooker, & Linebarger, 2009; Linebarger & Piotrowski, 2009). Linebarger and Piotrowski (2009) found that children who watched television programs with a narrative format (i.e., the different aspects of early literacy are embedded in a story) had significantly higher scores on book orientation and text comprehension than children who watched programs without a story context. Jennings et al. (2009) found that most educational television episodes pay attention to early literacy development by reading stories and showing animations combined with songs. However, they did not report significant effects of such television programs on children's early literacy development. 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, Johanson, Schneider, & Hutinger, 2008). According to Robinson et al. (2006), the resource system includes 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. However, no clear information was found concerning the effects of the recommended software titles on children's early literacy learning.

An overview of the studies that reported significant effects of the various software applications on children's early literacy development is provided in Table 2. In order to increase readability, we use footnote indicators to refer to the various studies in the literature review sample. The footnotes are explained both in Table 2 and at the end of the references section.

5.2. Design characteristics of the software applications that are effective in fostering kindergartners' early literacy development (TCK and TPK)

As mentioned in the previous section, there is empirical evidence of the effectiveness of the following software applications in fostering kindergartners' early literacy development: Electronic storybooks, computer-based phonics and vocabulary training programs, software applications that enable children to 'read and write', software applications that are designed for tutorial activities, and educational television programs with a narrative format. In the next paragraphs, we explore effective design characteristics of these software applications.

5.2.1. Electronic storybooks

The effect of electronic storybooks on children's early literacy development depends on the quality of the storybook. High quality electronic storybooks are characterized by 1) accessibility and user friendliness, and 2) specific functions that foster various aspects of early literacy development.

First, electronic storybooks should be suited to independent use by young children who are often not yet competent in reading the text by themselves. Thus, key characteristics of high quality electronic storybooks are oral reading of the printed text by a narrator (De Jong & Bus, 2004; Segal-Drori et al., 2010; Korat et al., 2009) and intuitive use of buttons, functions, and tools (Hornecker & Düsense, 2009).

Second, high quality storybooks contain specific functions that foster not only story comprehension and vocabulary development, but also children's book orientation and comprehension of alphabetic principle. For example, images that illustrate story fragments and elements, details or a complete story scene are a powerful function in fostering both story comprehension and vocabulary development (Verhallen et al., 2006; De Jong & Bus, 2004; Segal-Drori et al., 2010; Korat & Blau, 2010; Korat et al., 2009). In this respect, Verhallen et al. (2006, 2010) found that storybooks with multimedia and video images were more effective in fostering children's expressive vocabulary than storybooks with static images. Furthermore, specific functions that enable children to re-read and re-listen the text (De Jong & Bus, 2004; Segal-Drori et al., 2010; Korat et al., 2009) or that explain difficult words of the story (Korat & Shamir, 2008) also positively affect story comprehension and vocabulary development, because these functions provide an opportunity to have repeated encounters with the story content and visualize the meaning of particular words, respectively. Finally, children's book orientation and comprehension of alphabetic principle is fostered by a function that highlights written phrases when the text is declaimed and by forward and backward buttons on each screen (De Jong & Bus, 2004; Segal-Drori et al., 2010; Korat et al., 2009). Both the highlighting of text and the forward/backward buttons show children that books are read in a certain direction, namely at book-level from front to back, at page-level from page up to page down, and at sentence-level from left to right (cf. Verhoeven & Aarnoutse, 1999; Bronkhorst et al., 2009).

5.2.2. Computer-based phonics and vocabulary training programs

Computer-based phonics and vocabulary training programs could have a positive effect on children's early literacy development if they have certain design characteristics. Some of these characteristics can be considered as 1) general prerequisites for learning, whereas others refer to 2) effective instructional strategies for early literacy development.

First, in line with the work of Santoro and Bishop (2010), the quality of computer-based phonics and vocabulary training programs depends on the extent these programs could be judged 'instructional'. In other words, such software applications should comprise various general prerequisites for learning, such as a) accessibility and user friendliness, b) stimulating and maintaining engagement and motivation, and c) scaffolding and facilitating the learning process. Santoro and Bishop provide examples of these prerequisites, namely a) affordances and clues about functions or the operation of the program elements, b) aesthetically-pleasing and high-quality media and motivators within the program that drive the learner to action, and c) learner support, active use of (teacher) modeling and pre-correcting during instruction, and the capability to monitor, assess, and help direct learner progress.

Second, apart from these general prerequisites for learning, such training programs should apply instructional strategies that have been proven to be effective in fostering children's early literacy development. We noticed that most educational studies focus on effective instructional strategies in fostering phonics, namely strategies that foster phonemic and phonological awareness and alphabetic principle. In contrast, the two studies that investigated vocabulary training programs (Segers & Verhoeven, 2005: Segers et al., 2006) did not explicitly report effective instructional strategies for vocabulary development. Therefore, in describing these effective instructional strategies we narrow the focus to phonics training programs. In general, these instructional strategies are characterized by a) careful sequencing of tasks in order to scaffold linguistic complexity (Santoro & Bishop, 2010), b) explicit instruction of different letter-sounds, both productively and receptively (De Graaff...
et al., 2009), and c) effective mastery-promoting or drill-and-practice activities (Santoro & Bishop, 2010). According to Santoro and Bishop (2010), the careful sequencing of tasks in order to scaffold linguistic complexity is characterized by sequencing auditory skills from easy to more difficult, formulating instruction targets at different levels (e.g., sound, sentence, word, syllable, onset-rhyme, and phoneme level), and focusing on different aspects of alphabetic understanding (e.g., letter-sound correspondences, decoding and sounding-out skills, spelling, and word reading). The explicit instruction of different letter-sounds comprises the modeling of individual sounds that learners must produce and showing concrete representations in order to make children’s mental manipulations of sound explicit (Santoro & Bishop, 2010). Finally, effective mastery-promoting and drill-and-practice activities include repeated practice of letters in combination with pictures that are fading over time (De Graaff et al., 2007; 2009), identifying and reading words by blending its letter sounds and choosing matching pictures (Savage et al., 2009; Comaskey et al., 2009), rhyme and pattern recognition activities with words that are decodable and that include redundant patterns (e.g., matching words that rhyme, making words from the same word family by changing the first letter, matching words by their beginning sounds, and identifying similar words on the basis of their sound) (Savage et al., 2009; Comaskey et al., 2009; Santoro and Bishop, 2010), and introducing and reviewing word sets by practice with randomly presented words (De Graaff et al., 2009; Santoro & Bishop, 2010).

5.2.3. Software applications that enable children to ‘read and write’

Software applications that enable children to ‘read and write’ should be accessible in the first place, which is a general prerequisite for learning. This means that there should be an oral reading of the printed text by a narrator so that kindergartners could use the software independently. This function also increases children’s awareness that there is a difference between the act of ‘reading’ and

Table 2
Overview of studies that reported significant effects of particular software applications on children’s early literacy development.

<table>
<thead>
<tr>
<th>Software applications that are effective in fostering children’s early literacy development</th>
<th>Targets of the early literacy curriculum in kindergarten</th>
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<tr>
<td><strong>Book orientation and Text comprehension</strong></td>
<td><strong>Phonics (phonemic and phonological awareness &amp; alphabetic principle)</strong></td>
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<td><strong>Functions of print &amp; relations between spoken and written Language</strong></td>
<td><strong>Vocabulary development</strong></td>
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<tr>
<th>Electronic storybooks</th>
<th>3x RCT, 2x QES 1,2,6,7,8</th>
<th>4x RCT 2,1,2,5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Segal-Drori et al. (2010)</td>
<td>RCT</td>
<td>X</td>
</tr>
<tr>
<td>2 Korat and Blau (2010)</td>
<td>RCT</td>
<td>X</td>
</tr>
<tr>
<td>3 Korat et al. (2009)</td>
<td>RCT</td>
<td>X</td>
</tr>
<tr>
<td>4 Korat and Shamir (2008)</td>
<td>RCT</td>
<td>X</td>
</tr>
<tr>
<td>5 Shamir et al. (2008)</td>
<td>RCT</td>
<td>X</td>
</tr>
<tr>
<td>6 Verhallen and Bus (2010)</td>
<td>QES</td>
<td>X</td>
</tr>
<tr>
<td>7 Verhallen et al. (2006)</td>
<td>RCT</td>
<td>X</td>
</tr>
<tr>
<td>8 De Jong and Bus (2004)</td>
<td>QES</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Computer-based phonics and vocabulary training programs</th>
<th>A) phonics training</th>
<th>3x RCT 14,15,16</th>
<th>7x RCT, 3x QES 9,10,11,12,13,14,15,16,17,18</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) phonics training</td>
<td>9 Karemaker et al. (2010a)</td>
<td>QES</td>
<td>X</td>
</tr>
<tr>
<td>10 Karemaker et al. (2010b)</td>
<td>QES</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>11 Brabham et al. (2006)</td>
<td>QES</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>12 De Graaff et al. (2009)</td>
<td>RCT</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>13 De Graaff et al. (2007)</td>
<td>RCT</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>14 Savage et al. (2009)</td>
<td>RCT</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>15 Comaskey et al. (2009)</td>
<td>RCT</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>16 Penuel et al. (2012)</td>
<td>RCT</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>17 Macaruso and Rodman (2011)</td>
<td>RCT</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>18 Macaruso and Walker (2008)</td>
<td>RCT</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B) vocabulary training</th>
<th>19 Segers et al. (2006)</th>
<th>RCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 Segers and Verhoeven (2005)</td>
<td>QES</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other early literacy software applications</th>
<th>A) Software applications that enable children to ‘read and write’</th>
<th>3x CASE 21,22,23</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) Software applications that enable children to ‘read and write’</td>
<td>21 Cviko et al. (2012)</td>
<td>CASE</td>
</tr>
<tr>
<td>22 McKenney and Voogt (2009)</td>
<td>DESIGN/QES</td>
<td></td>
</tr>
<tr>
<td>23 Voogt and McKenney (2007)</td>
<td>DESIGN/QES</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B) Software applications designed for tutorial activities</th>
<th>1x QES 24</th>
</tr>
</thead>
<tbody>
<tr>
<td>B) Software applications designed for tutorial activities</td>
<td>24 Bauserman et al. (2005)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Educational television programs with a narrative format</th>
<th>1x QES 25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Educational television programs with a narrative format</td>
<td>25 Linebarger and Piotrowski (2009)</td>
</tr>
</tbody>
</table>

References to studies in the literature review sample by footnote indicators:

1 Segal-Drori et al. (2010); 2 Korat and Blau (2010); 3 Korat et al. (2009); 4 Korat and Shamir (2008); 5 Shamir et al. (2008); 6 Verhallen and Bus (2010); 7 Verhallen et al. (2006); 8 De Jong and Bus (2004); 9 Karemaker et al. (2010a); 10 Karemaker et al. (2010b); 11 Brabham et al. (2006); 12 De Graaff et al. (2009); 13 De Graaff et al. (2007); 14 Savage et al. (2009); 15 Comaskey et al. (2009); 16 Penuel et al. (2012); 17 Macaruso and Rodman (2011); 18 Macaruso and Walker (2008); 19 Segers et al. (2006); 20 Segers and Verhoeven (2005); 21 Cviko et al. (2012); 22 McKenney and Voogt (2009); 23 Voogt and McKenney (2007); 24 Bauserman et al. (2005); 25 Linebarger and Piotrowski (2009); 26 Santoro and Bishop (2010); 27 Hornecker and Dinser (2009); 28 Parette et al. (2008).
‘writing’ text; they learn that it is possible to pronounce written words (cf. Verhoeven & Aarnoutse, 1999; Bronkhorst et al., 2009). In the second place, other effective design characteristics that foster children’s comprehension of the functions of print are a) opportunities and functions to create, print, and save children’s own written products, and b) symbols that refer to speech act (e.g., a symbol that indicates ‘playing’ at the playground) (Cviko et al., 2012; McKenney & Voogt, 2009; Voogt & McKenney, 2007). The functions that enable children to create, print, and save their own written products foster their understanding of the permanent character of written language. In other words, they become aware that spoken words can be written down, for example by means of ICT. The use of symbols that refer to speech act fosters children’s understanding that written text and products serve a communicative goal (cf. Verhoeven & Aarnoutse, 1999; Bronkhorst et al., 2009).

5.2.5. Educational television programs

Finally, the study of Linebarger and Piotrowski (2009) showed that educational television programs with a narrative format were most effective in fostering children’s early literacy learning. However, apart from the narrative format, no other effective design characteristics were reported.

Table 3 provides a summary of the effective design characteristics of electronic books, computer-based phonics training programs, and software applications that enable children to ‘read and write’.

5.3. Effective use of ICT in order to create optimal learning opportunities with regard to early literacy development (TPACK)

The third research question focuses on how the software applications that were proven to be effective for early literacy development (see section 5.1) should be used in order to create optimal learning opportunities for kindergartners. We describe whether the studies under review provide empirical evidence or specific guidelines for teachers that explain how to use such software applications in the context of early childhood education.

5.3.1. Electronic storybooks

With regard to electronic storybooks, three recommendations for effective use could be made based on the empirical evidence, namely 1) repeated encounters with the story content (minimum of three to four), 2) adult support and adult instruction during and after the reading activity, and 3) reading the story in tutor-tutee pairs instead of individually. First, the studies of Korat and Blau (2010) and Verhallen et al. (2006) show that repeated encounters with the story results, on average, in larger improvement scores of children’s phonological awareness, concept about print, and emergent reading. In particular, these studies show that a minimum of three to four encounters with the story is required in order to gain significant results. Second, Segal-Drori et al. (2010) and Korat et al. (2009) found that adult support and adult instruction during and after the reading sessions could make a significant difference in the effect of electronic storybooks on children’s phonological awareness, concept about print, and emergent reading scores. Such adult support and instruction should focus on the discussion of print concepts and emergent literacy aspects during the reading activity. In addition, after the reading session, adults could increase the effect of reading electronic storybooks on children’s early literacy development by activities that are directly related to the story. For example, they could ask questions that link elements of the story to children’s personal life experiences. Third, the study of Shamir et al. (2008) compared the results of children that were reading the story on their own with those of children who read the electronic storybook in tutor–tutee pairs. In the latter condition, one of the children received instruction about the main modes and functions of the electronic book ahead of the reading session. This child was asked to act as a tutor during the reading session, for example by showing the other child how the software operates. The study showed that reading the story in tutor-tutee pairs resulted, on average, in larger phonological awareness and early literacy learning gains than reading the story individually. This was especially true for children in the role of tutor.

5.3.2. Computer-based phonics and vocabulary training programs

The studies under review that reported on the effects of computer-based phonics and vocabulary training programs do not provide concrete and specific guidelines or empirical evidence for the effective use of software applications specialized in teaching phonics/letter-sounds. However, with respect to software applications specialized in training vocabulary, a general recommendation can be made: The more time children spend on vocabulary learning games, the bigger their learning gains are (Segers & Verhoeven, 2005; Segers et al., 2006). The reason is that children’s vocabulary development is fostered by repeated encounters with new words together with extensive practice (cf. Verhoeven & Aarnoutse, 1999; Bronkhorst et al., 2009). It is reasonable to expect that the effect of such computer-based training programs on children’s vocabulary development increases when the learning of new words relate to a specific context or theme of importance to the children (Parette et al., 2008), because such words connect to children’s background knowledge or are embedded in a meaningful network of other words (cf. Verhoeven & Aarnoutse, 1999; Bronkhorst et al., 2009).

5.3.3. Software applications that enable children to ‘read and write’

Software applications that enable children to ‘read and write’, such as the PictoPal initiative and Writing with Symbols 2000, are effective tools in fostering children’s comprehension of the functions of print and relations between spoken and written language. The studies of McKenney and Voogt (2009) and Cviko et al. (2012) showed that the effect of such applications increased when 1) children have multiple/repeated sessions with on-computer activities and 2) on-computer activities are linked to off-computer activities in order to create meaningful learning experiences. First, the studies on the PictoPal initiative showed that children who attended at least eight on–computer sessions made significant early literacy learning gains compared to the control group (McKenney & Voogt, 2009; Cviko et al., 2012). Second, a significant effect on children’s knowledge of the functions of print was found when children’s own written products were used in a meaningful way by integrating these products in off–computer activities such as storytelling experiences and play (McKenney & Voogt, 2009; Cviko et al., 2012; Parette et al., 2008).

5.3.4. Software applications for tutorial activities

As mentioned in section 5.2, the study of Bauserman et al.
Table 3
Overview of effective design characteristics of software applications that foster children’s early literacy development.

<table>
<thead>
<tr>
<th>Effective design characteristics</th>
<th>Computer-based phonics training programs</th>
<th>Software applications that enable children to ‘read and write’</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. General prerequisites for both learning and kindergartners’ (independent) use of such software applications</strong></td>
<td>Accessibility &amp; user friendliness</td>
<td>Accessibility</td>
</tr>
<tr>
<td></td>
<td>- Oral reading of the printed text by a narrator/actor</td>
<td>- Oral reading of the printed text by a narrator/actor</td>
</tr>
<tr>
<td></td>
<td>- Intuitive use of buttons, functions, tools, etc.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Affordances or clues about functions or the operation of program elements</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stimulating and maintaining engagement and motivation</td>
<td>- Aesthetically-pleasing and high-quality media</td>
</tr>
<tr>
<td></td>
<td>- Motivators within the program driving the learner to action</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scaffolding and facilitating the learning process</td>
<td>- Learner support</td>
</tr>
<tr>
<td></td>
<td>- Active use of (teacher) modeling and pre-correcting during instruction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Capability to monitor, assess, and help direct learner progress</td>
<td></td>
</tr>
<tr>
<td><strong>2. Specific functions and instructional strategies that foster various aspects of early literacy development</strong></td>
<td>Fostering story comprehension and vocabulary development</td>
<td>Fostering children’s comprehension of the functions of print</td>
</tr>
<tr>
<td></td>
<td>- (Multimedia and video) images to illustrate story elements, details, fragments or the complete story scene</td>
<td>- Opportunities and functions to create, print, and save children’s own written products</td>
</tr>
<tr>
<td></td>
<td>- Function to re-read/re-listen the text</td>
<td>- Use of symbols to refer to speech act (e.g., a symbol to indicate ‘playing’ at the playground)</td>
</tr>
<tr>
<td></td>
<td>- Function that explains difficult words of the story</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fostering book orientation and alphabetic principle</td>
<td>- Introducing and reviewing word sets by extensive practice, for example with randomly presented words</td>
</tr>
<tr>
<td></td>
<td>- Written phrases are highlighted when the text is declaimed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Forward and backward buttons on each screen</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Careful sequencing of tasks in order to scaffold linguistic complexity</td>
<td>- Explicit instruction of different letter-sounds, both productively and receptively</td>
</tr>
<tr>
<td></td>
<td>- Sequencing auditory skills from easy to more difficult</td>
<td>- Modeling the individual sounds that learners must produce</td>
</tr>
<tr>
<td></td>
<td>- Instruction targets at different levels, such as sound level, sentence level, word level, syllable level, onset-rime level, and phoneme level</td>
<td>- Making learners’ mental manipulations of sound explicit by concrete representations</td>
</tr>
<tr>
<td></td>
<td>- Focus on different aspects of alphabetic understanding, such as letter-sound correspondences, decoding and sounding-out skills, spelling, and word reading</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Explicit instruction of different letter-sounds, both productively and receptively</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Effective mastery-promoting or drill-and-practice activities</td>
<td>- Carefully sequencing of tasks in order to scaffold linguistic complexity</td>
</tr>
<tr>
<td></td>
<td>- Repeated practice of letters in combination with pictures that are fading over time</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Identifying and reading words by blending its letter sounds and choosing matching pictures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Rhyme and pattern recognition activities with words that are decodable and that include redundant patterns; for example matching words that rhyme, making words from the same word family by changing the first letter, matching words by their beginning sounds, identifying similar words on the basis of their sound, etc.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Introducing and reviewing word sets by extensive practice, for example with randomly presented words</td>
<td></td>
</tr>
</tbody>
</table>

References to studies in the literature review sample by footnote indicators: 1 Segal-Drori et al. (2010); 2 Korat and Blau (2010); 3 Korat et al. (2009); 4 Korat and Shamir (2008); 5 Shamir et al. (2008); 6 Verhallen and Bus (2010); 7 Verhallen et al. (2006); 8 De Jong and Bus (2004); 9 Karemaker et al. (2010a); 10 Karemaker et al. (2010b); 11 Brabham et al. (2006); 12 De Graaff et al. (2009); 13 De Graaff et al. (2007); 14 Savage et al. (2009); 15 Comaskey et al. (2009); 16 Penuel et al. (2012); 17 Macaruso and Rodman (2011); 18 Macaruso and Walker (2008); 19 Segers et al. (2006); 20 Segers and Verhoeven (2005); 21 Ciklov et al. (2012); 22 McKenney and Voogt (2009); 23 Voogt and McKenney (2007); 24 Bauserman et al. (2009); 25 Linebarger and Piotrowski (2009); 26 Santoro and Bishop (2010); 27 Hornecker and Dünser (2009); 28 Parette et al. (2008).

(2005) showed that the effect of software applications that are designed for tutorial activities is highly dependent on the tutor, because the tutor plays an important role in keeping the child motivated when confronted with challenging and difficult learning tasks. In an attempt to engage the child in the various learning activities, the tutor used different elements of the program (e.g., rewards, motivators, and games) for own purposes. The study of Bauserman et al. did not report specific recommendations or guidelines for the effective use of such applications in the kindergarten classroom.

5.3.5. Educational television programs

Finally, with regard to the last category ‘educational television programs’, the literature does not provide concrete and specific guidelines and/or empirical evidence for optimal use of such programs in the kindergarten classroom.

A summary of the effective use of electronic books, computer-based vocabulary training programs, and software applications that enable children to ‘read and write’ is provided in Table 4.

6. Conclusions

The purpose of this literature review study is to describe the knowledge that is important for helping teachers and teacher educators to make informed decisions about using ICT to foster early literacy development in early childhood education. Three research questions have been formulated to guide the present study.

The first question addresses TCK by focusing on the software applications that are proven to be effective in fostering young children’s early literacy development. We found that the following types of software applications are effective in fostering children’s early literacy development: Electronic storybooks, computer-based
programs that are specialized in phonics and vocabulary training, software applications that enable children to ‘read and write’, software applications that are designed for tutorial activities in educational television programs with a narrative format. The effectiveness of electronic storybooks and computer-based phonics and vocabulary training programs is supported by empirical evidence derived from mainly randomized controlled trials, whereas the effectiveness of the other early literacy software applications is supported for the most part by quasi-experimental studies and case studies (see Table 2).

The second research question relates to both TCK and TPK, and focuses on the effective design characteristics of these software applications. We found that the literature was most explicit about the design characteristics of electronic storybooks, computer-based phonics training programs, and software applications that enable children to ‘read and write’ (see Table 3). With regard to the design characteristics of these software applications, a distinction can be made between a) general prerequisites for early literacy learning and the use of such software applications, such as accessibility and user friendliness, stimulating and maintaining engagement and motivation, and scaffolding and facilitating the learning process, and b) specific functions and instructional strategies that foster various aspects of early literacy development, such as specific functions to foster story comprehension, book orientation, vocabulary development, alphabetic principle, and comprehension of the functions of print and important elements of phonics instruction (e.g., scaffolding linguistic complexity and effective mastery-promoting activities).

The third research question pertains to TPACK and focuses on the effective use of the software applications mentioned before in order to create optimal early literacy learning opportunities for individual kindergartners. We found that the literature was often either not very explicit about how these applications should be used or did not provide convincing evidence for effective ICT-use. However, we found some general recommendations for the effective use of electronic storybooks, computer-based vocabulary training programs, and software applications that enable children to ‘read and write’ with symbols and words (see Table 4). These general recommendations can be summarized as follows: The effect of early literacy software applications on children’s early literacy development increases when 1) children have multiple and repeated encounters with the content of the software, 2) children are provided with adequate instruction and support, either by adults or by peer-tutors, during and after the on-computer sessions, and 3) on-computer activities are linked to off-computer activities in order to create meaningful learning experiences.

7. Discussion

7.1. The integration of ict in the daily practice of early childhood education

We started the present literature review with the notion that many teachers perceive the integration of ict in the daily practice of teaching as a challenging task (Labbo et al., 2003; Ertmer et al., 2012). We argued that teachers need to know what software applications are effective in fostering early literacy development order to make informed decisions about the selection and use of ict in early childhood education (research question 1). Moreover, they need to know about the effective design characteristics of such applications (research question 2) and how these programs should be used to create optimal learning opportunities for kindergartners (research question 3). On the basis of this review, we can say that teachers can make a huge step forward in the process of integrating ict by selecting high-quality electronic storybooks (that possess design characteristics such as mentioned in Table 3) and by treating those e-books as in integral part of the early literacy curriculum. In other words, when teachers succeed in planning for each child to receive repeated encounters with the story content accompanied with instruction and questions (that tie the story content to real life experiences), the effect of such electronic storybooks increases and the reading sessions become meaningful learning experiences. The next step could be to select other software applications that foster early literacy development (such as computer-based phonics and vocabulary training programs or software applications that enable children ‘to read and write’) by focusing on effective design characteristics (see Table 3) and by connecting on-computer activities to off—computer activities in a meaningful way.

However, in trying to formulate recommendations for teachers that struggle with the integration of ict in the daily practice of teaching, we noticed that the majority of the articles that were included in this review study remain silent about the effective use of these applications in the kindergarten classroom. In other words, there is a lack of clear and specific guidelines for teachers who wish to replicate the findings from isolated experiments. This makes it difficult for practitioners to make effective use of new media while also adhering to the principles of developmentally appropriate practices (DAP) in the context of early childhood education (cf. NAECY, 2009; NAECY and the Fred Rogers Center, 2012) in general, and related to literacy, specifically (NAEYC and IRA, 2009; Tafa, 2008). For example, scholars rarely formulate guidelines and criteria for effective instructional and classroom management strategies in relation to the specific technology and often they say
nothing about what off—computer activities should be linked to on-
computer activities. Thus, although strong evidence is found for the
effects of specific technology on children's early literacy develop-
ment, 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. Therefore, the
main implication of this literature review study is that scholars
should not only discuss the direct and indirect effects of particular
software applications on children's early literacy learning, but also
how (kindergarten) teachers should deal with moderating factors
such as learner characteristics, facilitating conditions, and curric-
ulum compatibility in relation to the particular software.

As mentioned in the first sections of this paper, one of the key
success factors for the effective integration of ict in the kinder-
garten classroom is a teacher's competence to make judgments
about the affordances of particular software applications for chil-
dren's early literacy development by using knowledge from the
different TPACK-domains (Koehler & Mishra, 2009; Voogt et al.,
2012). In addition, teachers should be able to translate their ins-
sights about the affordances of specific technology and ict-ap-
lications for early literacy education into personal heuristics,
instructional strategies, and design principles for technology-rich
learning environments. Various scholars have pointed out the
important 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 training should focus on. According to Hutinger, Bell, Daytner,
and Johanson (2005), curriculum integration training has more
impact on the integration of technology in teachers' early literacy
education than training in basic software skills (cf. Ilmeideh, 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 chil-
dren, fostering and facilitating peer interaction while conducting
on-computer activities (cf. Hutinger et al., 2005; Mitchell & Dunbar,
2006), and so on. Moreover, such 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 chil-
dren's early literacy development (cf. Robinson et al., 2006).

7.2. Limitations of the present study

Although this literature review study was conducted by care-
fully planned searching and selection procedures there are some
limitations. First, the articles were selected from databases that
mainly represent (general) educational research. This might have
led to an underrepresentation of insights from particularly the
linguistics about the use of ict in fostering kindergartners’ early
literacy development. A second limitation relates to potential bia-
ses in the corpus. It is possible that published reports emphasize
positive outcomes more than they do negative ones. Also, the
literature review focused on the significant effects of ict in relation
to the four strands that we distinguished in the targets of the early
literacy curriculum in early childhood education (i.e., book orienta-
tion and text comprehension, phonics (i.e., phonemic and
phonological awareness and alphabetic principle), functions of
print and relations between spoken en written language, and vo-
cabulary development). This focus might have caused that many
studies with valuable insights on the effective use of ict in the early
childhood classrooms were not discussed in detail in the results-
sections 5.2 and 5.3 because these studies reported non-signifi-
cant effects. And, of the cases studied, insufficient details were
available to compute effect sizes for all cases. This limits the
strength of the claims that can be made, especially with regard to

the first research question (software applications that are effective
in fostering kindergartners’ early literacy development based on
empirical evidence). To strengthen the claims, future review
studies could take into consideration how children’s performance
was measured and possibly conduct meta analysis using effect
sizes. Also, this study did not explicitly seek to understand longi-
dudinal effects or language-specific effects (cf. Manolitsis, Georgiou,
Stephenson, & Parrila, 2009), but these nuances might be incor-
porated in future research. Third, the four strands of the early
literacy curriculum mentioned might align more with the
competence of ‘reading’ and ‘writing’ and, as a consequence,
studies on the effects of ict in relation to the competences ‘listening’
and ‘speaking’ might have been less represented in the present
study. Finally, we did not include the ‘active engagement of the
teacher’ as an inclusion criterion, because that would lead to the
exclusion of many studies on the effects of electronic books on
children's early literacy development, because these studies focus
particularly on the independent practice of students. However,
this decision might have affected our results, in particular the result
that many articles did not provide clear and concrete recommenda-
dations in relation to the effective use of ict in the kindergarten
classroom (research question 3).

7.3. Towards a knowledge base for using ict to foster early literacy
development

Professional teacher behavior is characterized by an interaction
between teaching behavior, on the one hand, and teacher knowl-
edge and beliefs, on the other (Belo, 2013; Calderhead, 1996;
Verloop, Van Driel, & Meijer, 2001). In this respect, a key feature
of teacher professionalism is a teacher’s knowledge base of teaching.
Verloop et al. (2001) define this knowledge base as “all profession-
related insights that are potentially relevant to the teacher’s ac-
tivities” (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). This review study has contributed to this knowledge base by
focusing on the formal theoretical knowledge (TCK, TPK and
TPACK), that is important in helping teachers to make informed
decisions about the use of ict to foster early literacy development.
An important next step is to extend the knowledge base by focusing
on the experiential knowledge, beliefs, and practical arguments
that are important for selecting and using ict in early childhood
education. We suggest that a Delphi study with professionals that
are considered to be experts in one or more of the three TPACK
domains would be an excellent opportunity to gain insight in that
practical knowledge that is needed to create a justified rationale
for using ict to foster early literacy development.

This study has identified software applications that are effective
in fostering early literacy development in kindergarten. To a limited
extent, it also provides guidelines for selecting and using technol-
yogy for early literacy. However, given that the review was thorough
and the findings were limited, it also identified a lack of empirical
evidence related design characteristics of effective software appli-
cations and principles for effective use of technology to create
optimal technology enhanced learning related to early literacy. We
therefore conclude that there is currently insufficient empirical
work to guide both the design and the use of technology for early
literacy. Based on this extremely important, and well-grounded
conclusion, we call urgently for research to focus not only on
effectiveness of technologies for early literacy, but also on the
characteristics and use of specific applications so that their full
benefits may be identified and realized in practice.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.chb.2016.02.053.

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