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Title

Supporting secondary school students' reading comprehension in computer environments: A systematic review

Marlies ter Beek[1], Leonie Brummer[1], Anouk S. Donker, Marie-Christine J. L. Opdenakker

Groningen Institute for Educational Research, University of Groningen, The Netherlands

Notes
[1]. The first and the second author contributed equally to this paper.

Corresponding author:

Leonie Brummer

Groningen Institute for Educational Research, University of Groningen,

Grote Rozenstraat 3, 9712 TG, Groningen, The Netherlands.

Phone: +31 503635747
Email: l.brummer@rug.nl

Abstract

This systematic literature review analysed the content, focus, provision and effects of support (scaffolds) in computer environments with regard to secondary school students' reading comprehension outcomes. The relevant search terms yielded many hits (period: 2000-2017); however, intervention studies regarding reading comprehension of expository texts in computer environments seemed to be rather scarce. A careful analysis of these studies revealed that most of them provided cognitive support and some provided metacognitive support. Almost all studies focused on learning products, half of them in combination with learning processes. Most studies provided support in the form of statements, often provided during the task. Both cognitive and metacognitive scaffolds in computer environments produced a positive effect on reading comprehension outcomes. However, only one of the studies provided students with motivational scaffolds. Since the details of the design and content of the scaffolds used in all studies often remained unclear, it was difficult to determine the effectiveness of specific characteristics of scaffolds in computer environments. It is suggested that researchers should be more careful and comprehensive in designing and reporting on research in this area. Recommendations for future research and practical implementations of computer environments are presented.

Keywords: reading comprehension, computer environments, support, self-regulated learning, social studies

Introduction

Background

Being able to regulate your own learning is an important skill in secondary education. While in primary education teachers play an important role in their students' learning regulation and often direct and guide the learning of their students, students in secondary education have much more autonomy in regulating their own learning (Parsons, 2015). For example, they are expected to plan and monitor their own learning and to study the learning material independently. In secondary education, almost all learning material is provided by means of written texts. To study the learning material independently, students need to be able to read comprehensively and to process information adequately. Indeed, research has shown that these skills are essential for academic achievement (Cromley et al., 2010). In addition, Zimmerman (1990; 2008) argued that it is crucial for academic achievement that students are able to regulate their own learning processes and are able to motivate themselves to learn. The degree to which students are able to manage the regulation of their own learning (i.e., self-regulated learning) determines to a large extend whether they are able to succeed in secondary education and, subsequently, their possibilities for higher education and ultimately even their future career.

In secondary education, it is often assumed that students possess all these skills, yet it is known from research (e.g., Alexander, Graham & Harris, 1998) that students often have difficulties regulating their own learning and reading comprehensively. Teachers are often aware of these deficiencies; however, they face difficulties in instructing and supporting their students in developing these skills. An important reason is that it takes time and effort to integrate the required explicit instruction of learning strategies with adequate materials during regular content courses (Boekaerts & Corno, 2005; Lysenko & Abrami, 2014).

To help students to become self-regulated learners, attention should be paid to both the skill and the motivation to learn, since self-regulated learning relates to both the skill and the will to learn (Weinstein, Husman & Dierking, 2000). Self-regulated learning is considered to be comprised of three main aspects: cognition, metacognition and motivation. Cognition, in this respect, refers to the application of learning strategies: processes or sequences of processes that, “when matched to the requirements of tasks, facilitate performance” (Pressley, Goodchild, Fleet & Zajchowski, 1989, p.301). Metacognition refers to the regulation of the learning process such as monitoring progress, deciding upon the application of learning strategies and evaluating both learning processes and products. Motivation relates to the will component of self-regulation, as students who lack sufficient motivation do not engage in this type of learning behaviour (Weinstein et al., 2000). So, it seems obvious that learning environments that aim to support students in becoming self-regulated learners should pay attention to all three aspects. An example of integrating self-regulated learning in reading comprehension instruction is found in the intervention study of Souvignier and Mokhlesgerami (2006), which tested different versions of a strategy-instruction intervention among 593 fifth-graders in German language art classes. The researchers found that the version that incorporated cognitive, metacognitive and motivational aspects of self-regulation lead to improved reading comprehension outcomes, such as understanding of reading strategies and competence for application of reading strategies. Due to the combination of the self-regulation aspects students did not only increase their comprehension, but were also able to decide which strategy would be the most effective at a certain point. Additionally, students’ motivation to learn from text increased most in this condition. These improvements were found at retention tests and sustained in the long term.

In line with the aforementioned view on self-regulated learning, the results of Souvignier and Mokhlesgerami (2006) imply that to support students in the development of self-regulated learning skills, including the ability to read comprehensively, interventions should focus on these three components: cognition, metacognition and motivation. This focus requires increased effort from teachers, who should be able to provide instruction on both the content that has to be learned, and the process through which this should be learned best. Teachers need to be flexible and able to switch between different approaches to learning, matching both the abilities and preferences of students and the requirements of learning tasks. One way to support teachers in this process is by using supportive computer environments. Supportive computer environments are seen as learning tools that are “designed for instructional purposes and [that] use technology to support the learner in achieving the goals of instruction” (Azevedo, 2005a, p.193-194). Initially, these environments were no more than ‘books presented on a computer screen’; however, nowadays these computer environments have supportive features.

An advantage of these environments is that they are able to provide direct feedback and instruction based on students’ actions, which means a time-saving opportunity for teachers working with this kind of learning environments (Lysenko & Abrami, 2014). Another advantage is that students can navigate through such an environment individually. This provides opportunities for students to adjust their learning to their needs and preferences, such as the pace and approach of the learning task. This control of learning is known to enhance students’ involvement and motivation (Deci & Ryan, 2002) and also students’ transfer of learning (Jonassen, 2003; Moreno, 2006; 2009).

Computer environments

A large number of computer environments have been developed over the past decades. Following the rapid developments and the research regarding digital learning potential, recent meta-analyses have shed light on the effectiveness of these environments. For example, Moran, Ferdig, Pearson, Wardrop and Blomeyer Jr. (2008) analysed the effects of digital tools and learning environments on secondary school students' literacy acquisition, demonstrating that technology can have a positive effect on reading comprehension. However, their definition of technology was very broad and there were few intervention studies providing detailed findings on secondary grade levels. The study encouraged the research community "to redouble its efforts to investigate and understand the impact of computer environments on students in this age range and to broaden the scope of the interventions and outcomes studied" (Moran et al., 2008, p.7).

Cheung and Slavin (2012) reviewed 84 studies to investigate the effects of computer environments on the reading performance of K-12 students and found positive significant effects of computer environments compared to traditional environments, although the average effect size was relatively small. However, clear differences in effect size existed between the studies and it was found that characteristics of the environments and education level could explain differences in effect size. For example, more intensive interventions (i.e., more hours per week) resulted in larger effects. In addition, computer environments appeared to be more effective in secondary education compared to primary education. In addition, the effects of using computer environments were larger when teachers were actively involved in using these environments by adjusting their teaching to the environment and tailoring their instruction to complement the information provided in the learning environment (Cheung & Slavin, 2012). This indicates another major advantage of computer environments: they enable teachers to gain insight in students' learning processes and gives students the opportunity to receive more individually tailored instruction by making them less dependent on continuous supervision (Lynch, Fawcett & Nicholson, 2000; Lysenko & Abrami, 2014).

Support in computer environments: scaffolds

As computer environments rely on students' ability to regulate their own learning (Adeyinka & Mutula, 2010), a certain level of support is required. This support can help students to guide their learning in the computer environment and is often referred to as 'scaffold' (e.g., Aleven & Koedinger, 2002; Azevedo, 2005b; 2007). Scaffolds are defined as "tools, strategies and guides to support students in regulating their learning" (Lajoie, 2005, p. 547) and can be aimed at cognitive, metacognitive or motivational processes. These scaffolds can take many forms and serve many purposes. Cognitive scaffolding is meant to help the student solve a problem on his or her own (Lajoie, 2005). For example, cognitive scaffolds can provide more information to students regarding the content of the learning material. Metacognitive scaffolds are aimed at improving students' regulation of learning (for example by planning or evaluating results) which has proved to be an effective strategy for reading (Donker, de Boer, Kostons, Dignath-van Ewijk & van der Werf, 2014). Motivational scaffolds are meant to enhance student interest, learner control and affect (Lajoie, 2005). The question is which type of support should be provided and how this support should be provided to foster students' self-regulated learning ability and reading comprehension. This regards the form in which the scaffolds are presented, either as questions to trigger students' thinking or as prompts to activate students to take a certain action. Lastly, they can be either static (constant over time and the same for all students) or dynamic (individualized; Puntambekar & Hubscher, 2005).

The meta-analysis by Zheng (2016) examines the effects of different scaffolds in computer-based learning environments to determine which scaffolds are effective in supporting students' self-regulated learning and academic performance. For example, effects were largest for scaffolds aimed at a strategic level, such as providing different techniques or solution paths to a problem-solving question. Large effects were also obtained in studies with scaffolds aimed at both domain-specific (i.e., cognitive) and more general (i.e., metacognitive) content. Regarding school level, the largest effects were reported for students in secondary education; however, the article did not focus on the domain of reading comprehension. Another systematic review by Devolder, van Braak and Tondeur (2012) addressed the effectiveness of support focused on self-regulated learning in the domain of science. They reviewed 28 studies and found that most scaffolds were prompts that focused on students' cognition, for example, by providing a strategy such as highlighting to help students remember important information in a text. Metacognitive scaffolds, such as providing higher order questions, were offered less, yet most effective scaffolds were both cognitively and metacognitively oriented. Regarding effects on students' motivation, no clear conclusions could be drawn due to the small number of scaffolds aimed at increasing or sustaining motivation.

Lan, Lo and Hsu (2014) investigated a specific type of support that aims to foster reading comprehension: namely, the effects of metacognitive instruction in computerized reading contexts. Within the 17 studies found, 34% of the participants were from secondary schools. They found that metacognitive regulation as instruction proved to be "an effective form of instruction" for improving sixth- and seventh-graders (Lan et al., 2014, p. 196) and that secondary students greatly benefitted from vocabulary and comprehension support. However, the meta-analysis did not fully describe the contents of the metacognitive support provided, which makes it difficult to pinpoint which and to what degree different metacognitive instructional elements were effective for secondary students.

Aim of this study

Although the aforementioned findings provide insights with regard to the effect of support in computer environments in general terms, they do not provide detailed information about the contents of these environments and scaffolds. Lajoie (2005) indicates that support should at least focus on cognition and metacognition and preferably also on motivation, if students' self-regulation of learning is targeted. However, it is remarkable that research regarding these environments is frequently conducted in either primary or higher education, while particularly students in secondary education need help in regulating their learning. For example, the meta-analysis of Cheung and Slavin (2012) included 59 studies in primary education versus 18 in secondary education; Zheng's (2016) meta-analysis involved four articles about primary education, eight articles about secondary education and 17 in higher education. Reading goals and reading materials in secondary education differ from the goals and materials used in primary education and higher education. The studies conducted in secondary education are relatively scarce. As a result, little is known about which type of support is most effective in assisting students in secondary education to learn both content and effective learning strategies. The low number of studies conducted in secondary education provides a promising research area.

In addition, despite the presence of literature about support in computer environments in general, little is known about how to support reading comprehension and, in particular, the reading of expository texts in secondary education. This review addresses this research gap with two main research questions: First, what are the characteristics of support in computer environments which are aimed at fostering expository text reading comprehension in secondary education, and second, how effective is the support in these environments for students' reading comprehension outcomes?

To answer the first main research question, the following sub-questions are formulated:

RQ 1.1: What are the contents of support in computer environments aimed at expository text reading?

RQ 1.2: What is the focus of support in computer environments aimed at expository text reading?

RQ 1.3: In what ways is support provided in computer environments aimed at expository text reading?

By answering these questions, this review contributes to the research knowledge base focused on learning performance in general by narrowing the scope to reading expository texts and to students in secondary education. We aim to provide insight in how computer environments can be used to support students' learning by enabling them to self-regulate their learning and to support their ability to learn from texts. More specifically, we investigate which characteristics of support are effective in improving students' understanding of texts. In addition, we propose practical recommendations for researchers and teachers who want to provide or develop effective support in computer environments that include expository texts.

Method

Literature search procedures

The review included articles published between January 2000 and October 2017 and was restricted to English peer-reviewed articles. The search strategy encompassed a systematic search in peer-reviewed papers using the search databases ERIC and PsycINFO. The search was directed towards articles mentioning relevant terms, including digital environments[1], reading comprehension and support.

Search terms are displayed in Table 1. The search was conducted by combining at least two search terms from two different columns.

<insert Table 1 around here>

[1] In a preliminary search the search term 'online' was included as well. However, when checking the suitability of our keywords, we noticed that articles mentioning the term 'online' were directed towards reading websites or were focused on navigating through webpages. This focus did not fit the aim of this review.

After searching these online databases, it was decided to extend the literature search by browsing relevant educational and computer-related journals. Journals focusing on ICT structure in schools or programming aspects of digital environments were excluded. Journals were selected if at least three relevant abstracts with a focus on scaffold or support for reading comprehension appeared in the search hits. In total, 12 journals were selected (see Table 2). Every journal issue between January 2000 and October 2017 was scanned for titles and abstracts fitting the review scope.

<insert Table 2 around here>

Final selection of studies

The search provided 1151 hits and after removing the duplicates and scanning for inclusion/exclusion criteria 321 articles remained. The 321 abstracts were read more thoroughly and 304 articles were removed due to violating the inclusion criteria, such as 'involving an electronic, digital or computer environment'. Additionally, the search term 'tool*' was added in combination with the 'environment' and 'content' search terms and provided 451 hits including duplicates. However, an inspection of these articles revealed that no article met the inclusion criteria. As a result, no new articles were included in the review. In total, 17 articles were discussed in detail by two researchers and 12 were excluded afterwards. Articles were finally excluded due to three exclusion criteria, namely: (a) implementing the intervention with special needs children, (b) focusing on languages (e.g., English as a Foreign Language, or EFL) and (c) focusing on pen-and-paper reading comprehension interventions rather than on reading texts in digital environments. In sum, five articles were included in this review.

To be included in the current systematic review, studies had to meet the following criteria:

1. The studies implemented an intervention directed towards supporting reading comprehension.
2. The studies involved an electronic, digital or computer environment in which the reading task had to be completed.
3. Studies compared a reading intervention with a control condition with an absence or a different type of support.
4. The studies involved students from Grades 6 to 12.
5. The contents of the implementation were focused on content courses, such as geography, history, biology or other subjects with a rich use of expository texts.
6. The studies reported quantitative outcome measures related to reading comprehension.

In addition to the rather general inclusion criteria, specific exclusion criteria were comprised. The exclusion criteria were as followed:

1. Studies involving specials needs education (e.g., struggling readers, dyslexia, deaf/blindness and/or attention deficits) and remedial teaching.
2. Qualitative studies, such as case studies and interviews.
3. Meta-analyses or literature reviews.
4. Studies involving mathematics and/or foreign language learners (e.g., EFL).
5. Studies discussing narrative and/or fictional texts.
6. Studies solely focussing on technical reading skills (e.g., reading fluency and decoding).

Study coding

To code the studies in a systematic way, a coding scheme was developed.[2] The coding scheme was developed by two researchers based on earlier reviews (e.g., Devolder, van Braak & Tondeur, 2012) and included sample characteristics (e.g., research design, description of participants), task characteristics (e.g., subject, task description and instruction), support characteristics (e.g., focus and contents), and results and type of outcome measurement. The interrater reliability was a Cronbach's alpha of 0.70 with three coders. Due to the low number of included articles, all articles were collaboratively coded by three researchers. However, not every article reported the information needed for the review. Methodological specifications were collected by contacting the authors to study the detailed content of the support. To study the content of the support, we coded the support mentioned in the articles based on the learning strategy categories in Donker et al. (2014). The support either had a cognitive, metacognitive or motivational focus. Since the articles often did not label the support as being cognitive, metacognitive, or motivational, and not every article in this review clearly described what kind of support had been given, in most cases we had to assign the content of the support to one of the three aforementioned categories ourselves. When studies provided support on vocabulary items, definitions, or correct answers, we labelled the support as cognitive. When studies provided support on the learning process, such as prompts to think about learning strategies, we labelled the support as metacognitive. It was also possible that a combination of support types was found in the articles. The coding was based on the information provided in the text or derived from screenshots included in the article that displayed the support that had been given.

Results

Description of included papers

[2] This coding scheme is available upon request by one of the first authors.

All five articles in the current review showed that reading comprehension can be digitally supported in different ways.

Clay et al. (2009) focused on using a vocabulary tool (i.e., Visual Thesaurus; VT), for middle school students for social sciences. Data was collected in a randomized control trial by comparing the VT with the Merriam-Webster Online dictionary (MWO). The MWO only provided a definition of the selected word; the VT provided additional features (e.g., a word web, synonyms and antonyms). The procedure was similar for both conditions. Students read a text and completed a worksheet while reading online with either the VT or MWO. Performance measures were focused on vocabulary and content knowledge. Performance scores did not differ between the conditions.

Fry and Gosky (2007) investigated the impact of a pop-up dictionary on secondary school students' on reading texts online. Students in different grades were assigned to different reading sequences involving the pop-up dictionary, online texts without the pop-up dictionary, and hard-copy texts. For all sequences, participants read the text and answered multiple-choice questions. Scores on texts with the pop-up dictionary were compared to hard-copy texts or online texts without the pop-up dictionary. The pop-up dictionary was helpful for reading.

Gegner et al. (2009) supported secondary education students with comprehending scientific articles. Students read an article on a computer with or without digital aids. The digital aids were comprised of, for example, background information and questions for the author of the article. In addition, students could also use self-check question to assess their understanding. Measures of comprehension were compared between the two conditions and digital aids were useful in supporting the reading process.

The study by Lenhard et al. (2011) focused on strategy training programmes to foster metacognitive skills that should transfer to reading comprehension. Students received either teacher-directed instruction of declarative knowledge (i.e., *Reading Detectives*), or guided practice aimed at improving metacognition using a computer program (*conText*) and immediate feedback on written summaries. The training cycle in *conText* started for students with reading a text and writing a summary. *ConText* checked for orthography, plagiarism, redundant sentences and content coverage. The students got the possibility to improve their draft. The use of guided practice, as in *conText*, improved reading comprehension.

Finally, Llorens et al. (2016) studied the effects of automatic scaffolding directed towards promoting the transfer of self-regulation of strategic decisions during reading. Students read two texts and answered multiple-choice questions. They received scaffolds about their performance on questions for the first text, but not for the second text. Scaffolding was most effective when participants already had selected relevant text information to answer each question. Llorens et al. (2016) used the term ‘feedback’, whereas we use the term scaffolding to indicate the same concept. There is often no clear distinction between terms like scaffolding and feedback in existing research (Lajoie, 2005). From hereon we will continue using the term scaffolding when referring to this article.

General information

To understand the effectiveness of support, it is essential to consider the study characteristics, such as the participants’ grade level, the study domain, whether teachers were trained and whether the intervention was embedded in daily practice. These characteristics are displayed in Table 3.

<insert Table 3 around here>

The contents of support in computer environments aimed at expository text reading

The combination of cognitive and metacognitive support is effective for learning (de Boer et al., 2014). In total, three of the reviewed articles provided support with cognitive content, one article focused on metacognitive content, and one article combined cognitive, metacognitive, and motivational content in the digital support.

The studies by Clay et al. (2009) and Fry and Gosky (2007) provided support to the students in the form of a digital dictionary. Since a dictionary is solely aimed at knowledge of word definitions and supports students' vocabulary, we considered this cognitive support, providing information about the contents rather than the reading practice. Lenhard et al. (2011) addressed cognitive support by checking potentially redundant and irrelevant sentences in a summary, and by providing information about content coverage.

Llorens et al. (2016) emphasized the metacognitive strategy of reflection. Students in the 'select & revisit feedback' groups had to select the sentences relevant for their answer. The system recognized and highlighted the right answer and provided students with formative feedback about the correctness of their selected sentences. These students also had the opportunity to reread the text after this feedback message, which may evoke reflection and evaluation. Therefore, we labelled this feedback message as metacognitive support.

A combination of cognitive, metacognitive, and motivational support was addressed in the article by Gegner et al. (2009). Students could consult background information, interview questions and other information about the article. This information was labelled as cognitive. The metacognitive support was addressed by providing self-check questions. Next to the cognitive and metacognitive support, students were provided with motivational content (e.g., information about the author's choice of articles).

The focus of support in computer environments aimed at expository text reading

Support can be focused on learning processes (e.g., information processing and reflection upon this processing) as well as on learning products (e.g., performances or learning outcomes). Almost all studies focused on learning products and two studies also focused on learning processes. Llorens et al. (2016) focused on learning products. Participants received information about (a) the correct or incorrect answer, (b) the participants' *when* and *what* decisions, and (c) recommendations to re-visit the text and questions. In the study of Gegner et al. (2009) the support consisted of glossary terms and text highlighting (i.e., products) and self-check questions (i.e., process). Clay et al. (2009) designed the support in the form of two vocabulary tools, which were optional (i.e., process) for participants to extend their vocabulary (i.e., products). Lenhard et al. (2011) showed participants the content coverage of their draft (i.e., products) and this information was used for revision (i.e., process). In the study of Fry and Gosky (2007), the focus of the support could not be labelled due to a lack of information in the article.

In what ways is support provided in computer environments aimed at expository text reading?

Support can be provided in different forms (e.g., its design and content, static or dynamic) and during different stages of a text-based task (e.g., before, during or after reading). One study used visual support in the form of a bar chart with colour codes and labels indicating a *low*, *medium* and *high* result. Three studies used support in the form of statements. Support included correctness of the participants' answers, information regarding the decisions made by the participants during the masking phase, and recommendations to re-visit the text and the questions. One study used a combination of statements and questions for the format of the support. For example, statements were comprised of glossary terms and background knowledge, whereas questions were self-evaluative in nature.

In two studies, the support was adapted by the system, according to the correctness of answers and search strategies. In the study by Lenhard et al. (2011) the system flagged redundant sentences and indicated the content coverage in a bar chart which was different for each participant. Three studies used support that could be consulted by the participants when necessary, such as a digital dictionary and extra information.

Three studies used support during the task. In the studies by Clay et al. (2009) and Fry and Gosky (2007) digital dictionaries comprised the support during reading. Gegner et al. (2009) provided learning tools during the task that could be investigated, such as glossary terms, animations and background information. Support was provided afterwards by informing about the correctness of answers and about strategic search decisions during reading. The support also mentioned recommendations to re-visit the text and questions to detect what and why an answer was correct or incorrect. In the study by Lenhard et al. (2011), students who worked with *conText* received support during and after the reading task, while students who worked with *Reading Detectives* only received support afterwards. The remaining study by Llorens et al. (2016) only provided support after students finished the task.

The effect of the support on students' reading comprehension outcomes

In our review sample, all studies used a cognitive performance measure to test students' reading intervention outcomes, only one study (Lenhard et al., 2011) also measured metacognitive performance and another study (Gegner et al., 2009) reported motivational outcomes. With regard to the cognitive performance measures, three studies made use of standardized tests to measure reading comprehension, whereas two studies used researcher-developed tests (called either 'content measure' or 'comprehension test with 12 items'). However, the studies in which researcher-developed tests were used were not very informative about specific contents of the developed tests. In addition, information about the reliability of the test scores and the validity of the tests was not mentioned in the articles.

Effect sizes were displayed in three studies and in two studies the effect sizes could be calculated based on mean pretest and posttest scores, standard deviations and the number of participants (for Clay et al., 2009; Fry & Gosky, 2007). The partial eta-squared value (η^2 = .01) in the article of Llorens et al. (2016) was transformed to Cohen's *d* (Lipsey & Wilson, 2001) to report effect sizes consistently (see Table 3). All effect sizes only focused on cognitive performance. Effect sizes ranged from 0.02 to 1.23 and could be considered small to large (Ellis, 2010). None of the studies mentioned long-term results. As a result, we do not know whether the interventions' outcomes lasted a few weeks or months.

Conclusion

This review aimed to discover how scaffolds were designed in computer environments for supporting reading comprehension in secondary school students. Earlier meta-analyses regarding reading comprehension and technology (e.g., Cheung & Slavin, 2012; Moran et al., 2008) revealed the positive effects of digital scaffolds on reading comprehension, albeit mostly in higher education and primary education. Unfortunately, details about the specific characteristics of scaffolds in empirical research interventions often remain unclear (Devolder et al., 2012). The current review tried to fill this knowledge gap by primarily investigating interventions that use digital scaffolds to foster reading comprehension in secondary education.

A systematic literature search resulted in 321 articles, only five of which met the inclusion criteria. As Moran et al. (2008) already mentioned there is no heuristic for analysing digital technologies and their impact on adolescent literacy. This practical problem, combined with the limited amount of articles in this review, made an analysis of these scaffolds highly challenging. In this review, we focused on four essential characteristics: the content, focus, provision and effectiveness of these support characteristics. Three studies provided cognitive support, two studies also provided metacognitive support, and one study provided motivational support as well. Almost all studies focused on learning products, half of them in combination with learning processes. However, one study did not mention clearly what its focus was. Most studies provided support in the form of statements, often provided during the task. Both cognitive and metacognitive scaffolds in computer environments produced a positive effect on reading comprehension outcomes. Because of the diversity of the research studies that met our research criteria it is not possible to give an unambiguous answer to the question of which specific support characteristics in digital environments have effects on students' reading comprehension. Even when the content of the support was similar, such as the cognitive dictionary support in Clay et al. (2009) and Fry and Gosky (2007), design features or research methodologies were too different to draw any clear conclusions.

Nevertheless, the studies in this review provide some indications about which characteristics in a digital scaffolding environment positively influence students' reading comprehension. Examples of these characteristics are cognitive and metacognitive support features where students can (a) check for word meanings and background information, (b) receive information about content coverage in summarization tasks, (c) make self-check questions, or (d) receive the opportunity to re-read text to reflect on their answers. These digitally provided support characteristics all resulted in positive effect sizes ranging from small to large.

Discussion

This review study led to additional findings that should be taken into account when designing, reporting on and deciding to use a supportive program for reading interventions in secondary education. Firstly, literature related to digital interventions in secondary education was sparse. Whereas combinations of search terms such as ‘reading comprehension’ and ‘support’ yielded many hits, the addition of terms like ‘digital’ or ‘web-based’ mostly led to zero results. Earlier reviews and meta-analyses (Cheung & Slavin, 2012; Devolder et al., 2012; Lan et al., 2014; Moran et al., 2008; Zheng, 2016) showed the growing use of computer environments in education and their effect on learning products. However, they seem to be used within other subject domains like science and (mathematical) problem solving, or at other educational levels, like primary and higher education. One of the purposes of primary education is teaching students to read (Alexander, 2005). This requires a different approach for both instruction and support. Computer environments must have features to stimulate that purpose. In higher education, the continuation of reading to learn is present; however, learning in higher education requires a different approach. Due to the different learning situation in higher education, it would be infeasible to consider secondary and higher education as similar.

The specific focus on expository text reading in secondary education, without including the domains of language learning or mathematics, made clear that the research in this area is sparse and often remains unnoticed. Of the five studies found in this review, only one (Gegner et al., 2009) appeared in a previous meta-analysis (c.f. Lan et al., 2014). Despite the differences in educational levels, there are promising indications in the study of Cheung & Slavin (2012) that effect sizes of studies investigating the effects of technology applications on reading comprehension are on average higher for secondary education than for primary education (+0.31 and +0.10, respectively). However, the number of studies conducted in secondary education remains small.

Almost a decade ago, Moran et al. (2008) called for more extensive research in the area of reading comprehension in secondary education “to provide more specific and nuanced information about when, where, why and how technology can support teaching and learning for middle school literacy acquisition” (p. 28). However, our literature search shows that during the past ten years, few researchers have contributed to the field of digital reading comprehension scaffolding in secondary education. Several explanations are possible for this phenomenon; we will shortly address the two most plausible options.

One explanation for the sparse results is the fact that little research on expository text comprehension is conducted in secondary education, as Moran et al. (2008) already noted. This is remarkable because computers and digital environments are nowadays widely used in regular secondary education classrooms. Over the past few years, educational publishers have made great efforts to transform regular textbooks into a digital format suitable for computer, laptop, and tablet use. However, it remains unclear whether this digital format is the practical implementation of findings from scientific research. We would like to encourage the extension of research on the effects and effective characteristics of digital support in relation to expository text comprehension in Grades 6 to 12.

Another explanation concerns the predominant focus on struggling readers in most articles reporting reading comprehension interventions. In this review study, we excluded many articles because they focused on special needs education (e.g., remedial teaching, learning disabilities, struggling readers). It seems evident to us that reading interventions start at the level of the most struggling readers, but even in regular classrooms a lot of students experience difficulties in reading comprehension, as declining average reading performance in international measurements (OECD, 2016) show. Of the 1151 initial hits, only five articles eventually met all the inclusion criteria needed to answer our research question. Therefore, we recommend that future research should also focus on students without reading disabilities.

Implications for research and practice

Although the five studies included in this review are limited, we did discover some useful insights for both research and practice with regard to digital learning environments supporting expository text reading comprehension in secondary education. De Boer et al. (2014) argue that a combination of cognitive and metacognitive strategies is essential in learning. However, in the five articles in our review, there was little emphasis on metacognitive elements of reading. According to Lajoie (2005), it is also essential to combine cognitive and motivational support in learning. However, we found that only one of the interventions addressed motivational or affective scaffolding in its research design. This lack of attention towards motivation was already stressed by Moran et al. in 2008 and Devolder et al. in 2012. Although the only study in our review that addressed motivation reported more positive motivational beliefs in their experimental group (Gegner et al., 2009), little can be concluded about how students' motivation was influenced. Therefore, we would like to emphasize the addition of metacognitive and motivational support and outcome measures in computer environments. This helps us to gain an insight into the connections between cognitive, metacognitive and motivational aspects of support and outcomes related to reading comprehension.

Secondly, and surprisingly, many of the articles studied did not provide any information about the specific content of the scaffolds provided. Due to this lack of information, the replicability of the interventions – which is very important for scientific research – is questionable, depreciating the quality of research in this field. It is known that the scaffolds have an effect on student performance outcomes, but it is unclear which characteristics of the scaffolds are effective. Our descriptions of the scaffolds and their categories (cognitive, metacognitive or motivational) were based on general descriptions or screenshots included in the articles. All authors were e-mailed and asked for more detailed information, but unfortunately, details about the literal content of the scaffolds were not retrievable. A recommendation for further research would be to include specific details about the texts and scaffolds provided in the computer environment and about the outcome measurements used (such as texts, questionnaires and test items). This can be done in the article itself as well as by adding online supplementary materials to the original article.

Thirdly, most studies in this review were conducted in regular lessons with instruction provided by regular teachers and resulted in small to large effect sizes. This contradicts research showing that researcher-directed interventions often lead to higher effect sizes (de Boer et al., 2014; Dignath, Buettner & Langfeldt, 2008; Moran et al., 2008). We assume that co-operation between teachers and researchers and active involvement of teachers is of high importance with regard to the use of computer environments in secondary education. Especially younger secondary students, who are in transition towards more self-regulated learning, might benefit from the combination of teacher instruction and digital scaffolds. Like Moran et al. (2008) we would like to encourage the collaboration between researchers and teachers in this field. When teachers work with computer environments, their own contribution to student learning could be strengthened: both digital scaffolds and teacher instruction can support students' understanding. If the teacher is able to adequately integrate working with the computer environment in his or her own teaching and instruction practice, it will be even more beneficial for the teaching practice (i.e., more opportunities for monitoring and tailoring instruction) and for students' learning. One can assume that well-trained teachers who are actively involved in using a computer environment that has been worked out and meets all aspects of self-regulation approaches (Souvignier & Mokhlesgerami, 2006) will lead to the creation of more effective learning environments in daily practice.

Lastly, it would be worthwhile to combine quantitative and qualitative research methods (i.e., a mixed-methods study) to gain more insight into the mechanisms of digital interventions. In our literature search, we found either qualitative studies (e.g., case studies) or quantitative studies, but no mixed-methods designs. All of the studies in this review only provided quantitative analysis, which tells a lot about the effect in classrooms, but not about different outcomes on an individual level. With the developments in educational technology and the growing possibilities of learning analytics, we suggest that a focus on both the quantitative and the qualitative effects of digital support should be incorporated in future research studies.

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Table 1

Search Terms for the Systematic Review based on Terms for Environment, Content and Support

Environment	**Content**	**Support**	
Digital	Text* read*	Support*	Cue*
Web-based	Reading comprehens*	Scaffold*	Assist*
Computer	Text* comprehens*	Hint*	Strateg*
Computer-based		Tutor*	Tool*[a]
Electronic		Prompt*	

[a] Term added in a later stadium.

Table 2

List of Computer-Related Journals

Australasian Journal of Educational Technology
British Journal of Educational Technology
Computer Science – Research and Development
Computers & Education
Computers in Human Behavior
Education and Information Technologies
Educational Technology Research and Development
Electronic Journal on E-Learning
International Journal of Human-Computer Studies
International Journal on E-Learning
Journal of Computer Assisted Learning
Journal of Computer Science and Technology
Journal of Educational Multimedia and Hypermedia
Journal of Educational Technology & Society

Table 3 - *Overview of Study Characteristics of the Studies Included in the Current Review*

	Clay et al. (2009)	Fry & Gosky (2007)	Gegner et al. (2009)	Lenhard et al. (2011)	Llorens et al. (2016)
Grade	8	6, 7 and 8	11	6	7 and 8
Subject(s)	History	Social studies	Biology	Biology, history and geography	Biology
During regular lessons?	Unclear	Yes	Yes	Yes	Unclear
Instruction provided by	Trained teachers	Trained teachers	Trained teachers	Trained teachers	Unclear
Materials (texts) adapted from	Course book	Standardized test	Scientific articles	Unclear	Standardized test
Focus of scaffolds	Products and processes	Unclear	Products and processes	Products and processes	Products
How are scaffolds provided?	Statements	Statements	Statements and questions	Visuals	Statements
Content of scaffolds	Cognitive	Cognitive	Cognitive, metacognitive, and motivational	Cognitive	Metacognitive
Number of participants	212	37; 33; 59*	122; 97**	148	254
Study design	Pretest-posttest	Pretest-posttest	Pretest-posttest	Pretest-posttest	Pretest-posttest
Outcome measure	Designed by researchers	Standardized test	Designed by researchers	Standardized test	Standardized test
Effect size	*d* = .17	*d* = .09[a] *d* = .31[d] *d* = .88[b] *d* = .97[e] *d* = 1.23[c] *d* = 1.07[f] *d* = 1.08[g]	*d* = .79 *d* = .82	*d* = .33	*d = .02*

Note: **N* participants for grade 6, 7 and 8. ** *N* participants for Study 1 and Study 2.
[a]Grade 6 sequence 1 (pop-up vs. online). [b]Grade 6 sequence 2 (pop-up vs. online). [c]Grade 7 sequence 3 (pop-up vs. online). [d]Grade 6 sequence 1 (pop-up vs. text). [e]Grade 6 sequence 2 (pop-up vs. text). [f]Grade 7 sequence 3 (pop-up vs. text). [g]Grade 8 sequence 4 (pop-up vs. text). Effect sizes of Fry & Gosky (2007) are based on students' overall test score (Part A and part B).