Teaching Self-Regulation Strategies via an Intelligent Tutoring System (TuinLECweb): Effects for Low-Skilled Comprehenders

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Abstract

The use of documents to perform tasks is a continuous task demand in the current knowledge-based society that involves making a series of decisions to self-regulate the use of text information. Low-skilled comprehenders have serious problems monitoring and self-regulating their decisions in these task-oriented reading situations, which has a negative impact on performance and merits instructional interventions in school settings. Intelligent tutoring systems (ITSs) have emerged as effective tools to teach strategic skills. Herein, we present TuinLECweb, an ITS that teaches monitoring and self-regulation strategies to young adolescents. Study 1 explores whether high-skilled and low-skilled comprehenders respond to the intervention with TuinLECweb differently in terms of task-oriented reading performance and monitoring accuracy of non-search decisions. The results show that the intervention with TuinLECweb primarily benefits low-skilled comprehenders. Study 2 compares the efficacy of TuinLECweb over a classroom intervention for low-skilled comprehenders. The results reveal that TuinLECweb training improves monitoring accuracy of non-search decisions over and above classroom instruction. Both studies also reveal that low-skilled comprehenders use the strategies learned beyond the time of training. Our results provide arguments in favour of using computer-assisted programs in strategy instruction.

Introduction

The use of information to achieve goals (e.g., to decide which phone plan to purchase) is a constant demand in the current knowledge-based society (White, Chen & Forsyth, 2010). When taking in information, readers must not only understand what they read but also decide when they need certain information or what specific information is necessary to fulfil task requirements. These strategic decisions are essential in task-oriented reading, which is defined as a situation in which readers read one or more texts while knowing in advance that they will perform a task (e.g., answering questions) for which the texts are a crucial source of information (Vidal-Abarca, Mañá & Gil, 2010). International programs for the assessment of reading literacy skills, such as the Programme for International Student Assessment (PISA), have revealed that Spanish-speaking students score below the European average in understanding and using documents to respond to questions (Organization for Economic Co-operation and Development [OECD], 2010, 2014). Hence, it is no surprise that there is a growing interest in schools in preparing students to acquire those reading literacy skills. However, acquiring and improving complex cognitive skills often requires explicit strategy instruction, which has not received much attention in the classroom (e.g., Bjork, Dunlosky, & Kornell, 2013; Ness, 2011). Some possible explanations for this absence may be the challenge that strategy instruction presents in terms of teachers' resources and classroom time (Pressley, 2006) and the assumptions about what is important to teach (e.g., subject matter instead of strategies). In response to that, a new line of research based on the use of educational technologies has emerged over the last decade. Several intelligent tutoring systems (ITSs) have been developed to teach reading comprehension strategies (Johnson-Glenberg, 2005; McNamara, Levinstein, & Boonthum, 2004; Potocki, Ecalle, & Magnan, 2013; Wijekumar, Meyer, & Lei, 2012). However, to our knowledge, no current ITSs focus on teaching task-oriented reading strategies. Here, we present an ITS called TuinLECweb that teaches and trains task-oriented reading skills to young adolescents. It has demonstrated effectiveness in improving task-oriented reading performance in 6th grade students (Vidal-Abarca et al., 2014). However, this preliminary study did not address two important issues: 1) how different students respond to TuinLECweb, not only in terms of performance but also in terms of decision-making processes, and 2) its efficacy relative to a traditional teaching method. The goal of the two studies in this article was to examine these two specific issues, the results of which would contribute to the field of strategy instruction and computer-based interventions.

In the next section, we summarise the main processes and decisions involved in task-oriented reading, as well as individual differences in these processes and decisions. Afterwards, we give an overview of the advantages of ITSs over traditional teaching methods and present some evidence of their efficacy to improve reading comprehension and strategy use. Finally, we present TuinLECweb.

Task-oriented reading: processes and decisions

Effectively making use of texts to perform particular tasks requires specific literacy skills that extend beyond reading comprehension (Cataldo & Oakhill, 2000; Rouet, 2006). These reading situations, usually called task-oriented reading (Vidal-Abarca et al., 2010), are considered problem-solving situations (Britt, Rouet, & Durik, 2017) in which readers establish goals and make a series of self-regulation decisions, such as what to read and how to read it, until the goals are met (Rouet, 2006; Rouet, Britt, Durik, 2017). These decisions are mainly based on metacognitive processes and influence students' level of success in the task (Gil, Martínez, & Vidal-Abarca, 2015; Vidal-Abarca, Salmerón & Mañá, 2011). One common task-oriented reading situation that students encounter is reading to answer questions. In instructional settings, students are frequently asked to answer questions about a text as a means of learning academic content or comprehension skills (Ness, 2011). International programs for the assessment of reading literacy skills (PISA, OECD, 2010) and standardized reading comprehension tests (CompLEC, Llorens et al., 2011; PROLEC-SE, Ramos & Cuetos, 1999) show a similar structure. To understand a task-oriented reading situation, imagine that a reader is presented with a text and a set of questions with the instruction to use the text to respond to the questions. Very often students decide to read the text first and then to respond to the respond the questions (Vidal-Abarca, Martinez, et al., 2011; Vidal-Abarca, Salmerón, et al., 2011). In this case, the student first needs to understand what he/she is asked to do; that is, he/she must build a task model (Rouet, 2006; Rouet & Britt, 2011), which is a representation of the goal to be achieved and the means to achieve it (Rouet et al., 2017). The task model will drive the student's decisions, such as the decision to search for text information or to answer the question from memory. If the decision is no-search, the response is created and given, but if the student decides to search the text, he/she will have to assess what text information is relevant to achieve his/her goal (McCrudden & Schraw, 2007).

The decision to search the text is a crucial metacognitive decision that has been shown to be related to task-oriented reading performance (Gil et al., 2015; Llorens, Cerdán, & Vidal-Abarca, 2014; Mañá, Vidal-Abarca, & Salmerón, 2017). This decision requires a preparatory monitoring phase during which the student assesses his/her level of necessary knowledge for answering the question (Vidal-Abarca et al., 2010). Such self-assessment of one's need for information can be a challenge for many students as it relies mostly on one's self-monitoring skills (Pressley & Ghatala, 1990; Rouet & Coutelet, 2008). This decision is similar to the process investigated in the *Judgments of Learning* (JOL) paradigm. In this paradigm, people predict how well they learned particular information; after that, the students' comprehension is assessed, and the predicted and actual performance are compared (e.g., Dunlosky & Nelson, 1992; Thiede, Anderson, & Therriault, 2003). A high correlation between prediction and performance indicates good monitoring accuracy, whereas a low correlation indicates poor monitoring accuracy (Maki, 1998). In task-oriented reading situations, this paradigm has been used to investigate the similarity between search decisions and JOLs (Vidal-Abarca et al., 2010). The authors found that having low confidence in what one has learned from the text led to a decision to search the text further before answering a question, whereas high confidence led to a decision not to search the text.

Research in self-regulated learning shows that monitoring accuracy is critical to learning since it provides a basis for making self-regulation decisions (e.g., reviewing the material), which, in turn, has been related to test performance (Thiede et al., 2003). Similarly, in task-oriented reading, monitoring of one's need for information has been shown to be related to search decisions, which has been related to task-oriented reading performance (Gil et al., 2015; Llorens et al., 2014; Mañá et al., 2017).

Evidence suggests that some task-oriented reading processes and decisions are highly dependent on comprehension skills. Low-skilled comprehenders have trouble forming a coherent task model, which then has consequences for the search process and successful task completion (Cerdán, Gilabert, & Vidal-Abarca, 2011; Vidal-Abarca et al., 2010). Vidal-Abarca et al. (2010) also demonstrated that good comprehenders select and use relevant information more often than poor comprehenders during text searching, which indicates that the latter have problems assessing what text information is relevant to the task. In addition, Cataldo and Oakhill (2000) revealed that good comprehenders are more strategic searchers compared to poor comprehenders. Regarding monitoring accuracy, although a substantial number of studies have concluded that it is independent of comprehension skills, others have concluded that low-skilled comprehenders are overconfident in their understanding of the text (see Maki, Shields, Wheeler, & Zacchilli, 2005, for a review). Vidal-Abarca et al. (2010) found that low-skilled comprehenders usually fail to give the right answer when they decide not to search, indicating poor monitoring accuracy. Ramos & Vidal-Abarca (2013) found individual differences in the minimum level of subjective comprehension students need to decide not to search the text before answering a comprehension question. Whereas high-skilled comprehenders decided not to search when their JOL was 80% or higher, low-skilled comprehenders were satisfied with a moderate level of subjective comprehension (i.e., JOL 60%).

In sum, using texts to answer questions involves a series of actions and decisions that depend on cognitive and metacognitive skills and impact performance. Metacognitive monitoring and regulation skills play a critical role in task-oriented reading. Accurate monitoring of one's information needs is the basis for proper self-regulation. Therefore, it is necessary for students to be able to distinguish when they have enough information to answer a question and when they do not, and when they understand the question or the relevant information and when they do not. This has important implications for self-regulation processes, as an inaccurate assessment of one's information needs or one's understanding, in which the student believes that he/she knows more than he/she really knows, can lead to taking inadequate steps to achieve the task's objective (for example, not to re-read the text) (Winne & Hadwin, 1998). Thus, it seems necessary to attach importance to monitoring in task-oriented reading instruction, especially for low-skilled comprehenders, who show important deficits in using metacognitive strategies (e.g., Garner, 1987). Research on self-regulated learning suggests that the ability to monitor and regulate one's learning can be enhanced via metacognitive strategy instruction on how to use particular strategies and when and why to employ them (Huff & Nietfeld, 2009). Computer-based systems offer new opportunities to effectively provide strategy instruction.

Intelligent tutoring systems for strategy instruction

ITSs are computer learning environments that help students acquire knowledge or skills by implementing intelligent algorithms that adapt to the student (Graesser, Conley, &

Olney, 2012). An ITS tracks the student's psychological states (such as subject matter knowledge, learning strategies, or motivations) and adaptively responds with individualised instruction and timely adaptive feedback.

ITSs offer distinct advantages over traditional classroom teaching or human tutoring. First, ITSs have the potential to implement sophisticated tutoring strategies (e.g., modelling-scaffolding-fading, reciprocal teaching) that have been shown to be effective in the field of education. Some studies have shown that such sophisticated strategies, however, are rarely implemented by human tutors (Graesser, D'Mello, & Person, 2009).

Another advantage of computer-based systems is that they provide greater opportunities for practice and feedback (Martin, Klein, & Sullivan, 2007) and allow the student to have more interactions with the system than with a single teacher in a traditional classroom. This is a key element in skills acquisition since developing and improving new complex skills usually require a significant amount of practice with formative feedback over an extended period of time (Butler & Winne, 1995; Duke & Pearson, 2002; Ericsson, Krampe, & Tesch-Römer, 1993). Specifically, the effectiveness of computer-based instruction has been mainly attributed to the immediacy of feedback and its adaption to the specific student's response (Azevedo & Bernard, 1995), something that is not possible in large classroom settings. In strategy instruction, adaptive formative feedback that inform students on the correct strategy has been shown to be effective in improving students' comprehension performance and strategic decisions (e.g., Llorens et al., 2014; Llorens, Vidal-Abarca, & Cerdán, 2016). In a recent study (Llorens et al., 2014), students received adaptive feedback that provided information about the students' strategic decisions (i.e., when and what information to search) and their performance while they were trained to answer questions from texts. Students that received formative feedback improved their search decisions and focussed on relevant text information to a greater extent than the students that only received feedback about the correctness of their answers.

Meta-analysis and reviews have supported the claim that ITS technologies improve learning over and above classroom teaching and/or other traditional learning methods (e.g., Ma, Adesope, Nesbit, & Liu, 2014; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011; VanLehn, 2011). In the field of reading comprehension, for instance, several ITSs have demonstrated significant improvements in students' comprehension performance and strategy use (e.g., 3D-Readers: Johnson-Glenberg, 2005; Interactive Strategy Training for Active Reading and Thinking, iSTART: McNamara et al., 2004; LoCoTex: Potocki et al., 2013; and Intelligent Tutoring for the Structure Strategy, ITSS: Wijekumar, et al., 2012). However, to our knowledge, no computer-based systems have been developed to teach task-oriented reading strategies. In response to that, Vidal-Abarca and colleagues developed TuinLECweb, which is an improved version of TuinLEC (see a complete description in Vidal-Abarca et al., 2014), to teach strategic knowledge and train self-monitoring and self-regulation strategies in task-oriented reading situations.

TuinLECweb: An Intelligent Tutoring System

TuinLECweb consists of eight lessons distributed into two phases: the instructional phase and the practice phase. In the first phase, TuinLECweb provides instruction on the strategic decisions that readers must make in task-oriented reading situations, with special emphasis on monitoring accuracy. Students learn how to form an initial representation of the text, how to build a task model, how to search the text, and how to accurately monitor and self-regulate one's need to search for information. The metacognitive strategy instruction is conducted through explicit instruction, modelling and guided practice via dialogs between two animated agents. It combines instruction on how to use monitoring and self-regulation strategies with an emphasis on the conditional knowledge of when and why to use such strategies since they are key elements in self-regulated learning (Baker & Brown, 1984). After the instructional phase, students are trained through extensive practice consisting of using information from real texts to answer multiple-choice questions. Students receive computer-generated formative and adaptive feedback based on their performance and strategic search decisions, which are crucial in question answering (Gil et al., 2015; Mañá et al., 2017).

A study by Vidal-Abarca et al., (2014) showed the efficacy of an intervention with TuinLEC (the previous version of TuinLECweb) to improve task-oriented reading performance in 6th grade students. However, important issues remain in need of further investigation, including (a) how students with different comprehension skills respond to TuinLECweb, not only in terms of performance but also in terms of monitoring accuracy, and (b) the efficacy of this computer-based intervention compared with traditional classroom instruction. The first question is especially relevant because individuals with different comprehension levels differ in their use of task-oriented reading strategies (Cataldo & Oakhill, 2000; Maki et al., 2005; Vidal-Abarca et al., 2010) and in the impact that these strategies have on performance (Gil, et al., 2015; Vidal-Abarca et al., 2010). Regarding this issue, some studies have found that strategy instruction particularly benefits low-skilled comprehenders (Raphael & Pearson, 1985). In the field of literacy instruction, computer-based systems have also been shown to be particularly effective for low-ability readers (Johnson-Glenberg, 2005; O'Reilly, Best, & McNamara, 2004; Potocki, et al., 2013). With respect to the efficacy of a computer-based intervention over a traditional classroom intervention, some meta-analyses and reviews have shown that ITSs are more effective than classroom teaching in improving learning (e.g., Ma et al., 2014; Tamim et al., 2011; VanLehn, 2011).

In this article, we present two studies. The first study examines the extent to which high-skilled and low-skilled comprehenders respond differently to the intervention with

TuinLECweb in terms of task-oriented reading performance and monitoring accuracy of non-search decisions. The second study compares the efficacy of TuinLECweb relative to traditional classroom intervention on low-skilled comprehenders' performance and monitoring accuracy of non-search decisions. In contrast to previous studies with this ITS, the effects of TuinLECweb were analysed not only at a post intervention but also at a 2-week follow-up to assess the stability of the effects after a delay without training.

Study 1

Objectives and hypothesis

The first aim of Study 1 was to analyse whether high-skilled and low-skilled comprehenders respond differently to an intervention with TuinLECweb in terms of task-oriented reading performance and monitoring accuracy of non-search decisions. The second question to be explored was whether the effects are maintained in the long-term. Our hypotheses were that TuinLECweb would be more beneficial for low-skilled comprehenders, who may lack appropriate strategies to be competent in these situations, and that the benefits would be maintained after 2 weeks.

Method

Participants

Forty-seven students were selected from 4 sixth- and seventh-grade classrooms from two public schools in Valencia, Spain. A reading comprehension test was administered to all the students as a means of selecting the sample for both groups (a description of the test is presented later). The sample of high-skilled comprehenders was composed of the students above the 60^{th} percentile (n = 24; 15 females), while the sample of low-skilled comprehenders comprised students below the 40^{th} percentile (n = 23; 11 females).

Measures

Reading comprehension

Students' reading comprehension was assessed using the Test of Comprehension Processes (TPC; Martínez, Vidal-Abarca, Sellés, & Gilabert, 2008), which is a Spanish standardised test designed to tap comprehension processes following Kintsch's (1998) Construction-Integration model. It consists of two expository texts with 10 multiple-choice questions per text.

Task-oriented reading performance

Students' task-oriented reading performance was assessed at the three time points (pre-test, post-test and follow-up) with a task consisting of 2 texts and 12 multiple-choice and open-ended questions. Three similar task-oriented tests were developed using texts and questions already tested. The order of application of the three tests was counterbalanced within participants and between moments. The tests were presented using the application Read&Answer (Vidal-Abarca, Martínez et al., 2011), which records the students' reading behaviour.

Monitoring accuracy of no-search decisions

Monitoring accuracy of no-search decisions (i.e., how accurate a student was when he/she decided not to search before answering a question) was assessed using a gamma coefficient similar to that computed in JOL studies to measure the JOL's accuracy (e.g., Nelson, Narens, & Dunlosky, 2004). This coefficient is a measure of relative metacomprehension accuracy and was obtained by the following formula, used by Vidal-Abarca et al. (2010): $[(\sum C - \sum W) / (\sum C + \sum W)]$, where C is the number of right answers when the student decided not to search, and W is the number of wrong answers when the student made the same decision. When the number of right answers (C) is higher than the number of wrong answers (W), the gamma is positive; otherwise, it is negative.

Procedure

This study uses a pre-test/post-test/follow-up design. During the pre-test, students completed the task-oriented reading test. The training period started the day after the pre-test session. Students were trained with TuinLECweb 2 days a week for 4 weeks. The average time per session was 45 minutes in the instructional phase and 25 minutes in the practice phase. All students completed a post-test and a follow-up test (both similar to the pre-test), the day after and 2 weeks after the intervention, respectively. All of the sessions took place in the computer lab of each school.

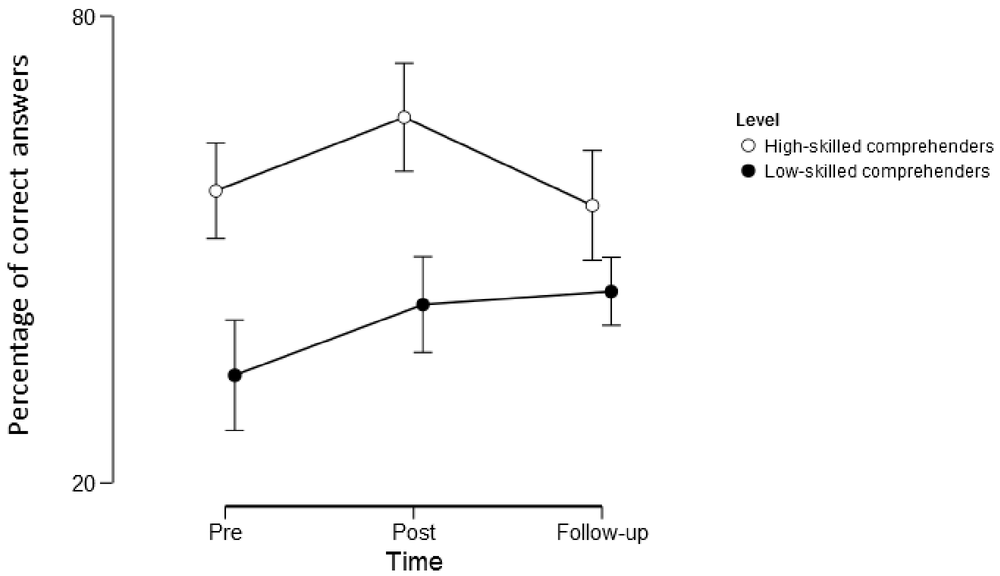
Results

Analyses examined the effects of TuinLECweb on students' task-oriented reading performance and monitoring accuracy of non-search decisions. To test our hypothesis, 2 two-way mixed ANOVAs were conducted with comprehension level (high-skilled, low-skilled) as a between-groups variable, time (pre-test, post-test, and follow-up test) as a within-subjects variable, and performance and gamma scores as dependent variables.

Performance in task-oriented reading

The results showed a main effect of time, $F(2,90) = 4.53$, $p = .013$, $\eta^2_p = .09$, and a trend towards significance in the interaction effect between time and comprehension level, $F(2,90) = 2.90$, $p = .060$, $\eta^2_p = .06$ (see Figure 1). Table 1 reports the mean values and standard deviations by group. Bonferroni post hoc tests revealed that low-skilled comprehenders performed better on the follow-up test than on the pre-test (p=.045), whereas high-skilled comprehenders' performance on the follow-up test did not differ from the pre-test (p=1.00). The differences between pre-test and post-test were not significant for high-skilled (p=.137) or low-skilled (p=.178) comprehenders.

Figure 1. Performance in task-oriented reading by comprehension level.



Monitoring accuracy of non-search decisions

The results showed a non-significant interaction effect between time and comprehension level, $F(2,88) = 1.20$, $p = .307$, $\eta^2_p = .03$ (see Figure 2). Table 1 reports the mean values and standard deviations by group. Bonferroni post hoc tests revealed a non-significant tendency of high-skilled comprehenders to monitor better on the post-test than on the pre-test ($p = .062$), whereas performance on the follow-up test did not differ from the pre-test ($p = .730$). Low-skilled comprehenders' scores on the pre-test did not differ from the post-test ($p = .679$), although they did show a non-significant trend on the follow-up test ($p = .125$; $p = .042$ if we remove post-test values from the analysis). Bonferroni post hoc also showed significant differences between high-skilled and low-skilled readers on the pre-test ($p = .045$) and the post-test ($p = .001$), whereas on the follow-up test, the differences between both groups were non-significant ($p = .105$).

Figure 2. Monitoring accuracy of non-search decisions by comprehension level

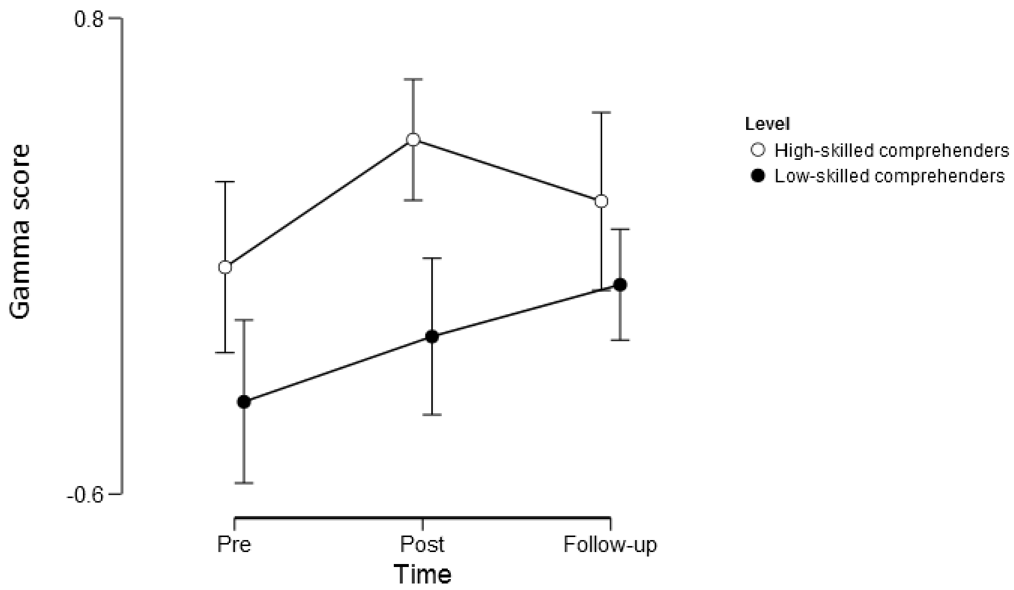


Table 1. Means and standard deviations (in parentheses) of task-oriented reading performance and monitoring accuracy of non-search decisions by comprehension level.

Comprehension level	Performance			Monitoring accuracy of non-search decisions		
	Pre	Post	Follow-up	Pre	Post	Follow-up
Low (*n* = 23)	33.85 (18.26)	42.94 (19.06)	44.63 (19.23)	-.33 (.55)	-.14 (.55)	-.02 (.50)
High (*n* = 24)	57.56 (20.28)	67.00 (17.19)	55.67 (15.56)	.07 (.73)	.44 (.55)	.26 (.50)

In summary, the results of Study 1 indicate that the intervention with TuinLECweb seems to improve low-skilled comprehenders' performance and monitoring accuracy in the long-term, whereas high-skilled comprehenders do not seem to benefit from the intervention.

Study 2

Objectives and hypothesis

The first aim of Study 2 was to replicate the results of Study 1 in a sample of low-skilled comprehenders. We hypothesised that the results would be similar to those found in the previous study regarding the benefits of TuinLECweb for low-skilled comprehenders in both performance and monitoring accuracy of non-search decisions. The second aim was to examine the effectiveness of TuinLECweb over and above traditional classroom instruction in reading comprehension to improve task-oriented reading performance and monitoring accuracy of non-search decisions. We predicted that TuinLECweb would be more effective than classroom instruction. The third aim was to explore the long-term effects of both interventions. We predicted that the effects of TuinLECweb would emerge on the follow-up test, whereas results at the post-test would not be significantly different from those of the pre-test, as revealed in Study 1.

Method

Participants

Sixty-eight low-skilled comprehenders (38 females) were selected from 8 sixth-grade classrooms from one public school and three private schools in Valencia, Spain. Students were administered the TPC reading comprehension test (Martínez et al., 2008) as a means of selecting the low-skilled comprehenders (scores below the 40^{th} percentile).

Measures

The measures for Study 2 were the same as those for Study 1: reading comprehension, task-oriented reading performance and monitoring accuracy of non-search decisions. Likewise, the materials used were the same as in Study 1 except for the task-oriented reading test, which was extended to 3 texts and 15 multiple-choice and open-ended questions for each test. As in Study 1, three similar task-oriented tests were developed using texts and questions already tested. The order of application of the three tests was counterbalanced within participants and between moments. The tests were presented using Read&Answer software (Vidal-Abarca, Martínez et al., 2011).

Procedure

As in Study 1, this study employed a pre-test/post-test/follow-up design. During the pre-test, students completed the task-oriented reading test. The training period started the day after the pre-test session. All students were randomly assigned to either the TuinLECweb group (n = 35) or the workbook group (n = 33). There were no differences between conditions in reading comprehension measured with the TPC, $t(66) = 0.159$, $p = .874$. All students were trained with either TuinLECweb or the workbook “Aprender a Comprender” (or “Learning to Understand”, see a description of the conditions later), 2 days a week for 4 weeks. The average time per session was similar in both conditions. All students completed a post-test and follow-up test (both similar to the pre-test), the day after and 2 weeks after the intervention, respectively. All sessions took place in the computer lab of each school.

Experimental conditions

Students in the TuinLECweb condition completed the TuinLECweb training program (see a brief description of the software in the section of this study entitled “TuinLECweb: An Intelligent Tutoring System”). Students in this condition trained independently with the system.

Students in the workbook condition completed a workbook-based program called “Aprender a Comprender” (“Learning to Understand”) level 4, designed for 6th grade students (Vidal-Abarca et al., 2003). This workbook-based program teaches comprehension strategies for understanding texts. It is divided into 14 different lessons, each with one text and approximately 16 activities that include hints and recommendations, so that the student can complete them on his/her own with minimal guidance from the teacher. Teachers were trained to implement this program per certain guidelines. Hence, in every session, the students read the texts and completed the activities independently. Once all of the students were finished, the teachers corrected all the activities aloud while the students checked their answers. Teachers were available to answer any question raised by the students at any moment.

Results

Analyses examined the effects of TuinLECweb over traditional classroom instruction on students' task-oriented reading performance and monitoring accuracy of non-search decisions. To test our hypothesis, 2 two-way mixed ANOVAs were conducted with condition (TuinLECweb, workbook) as a between-groups variable, time (pre-test, post-test, follow-up test) as a within-subjects variable, and performance and gamma scores as dependent variables.

Performance in task-oriented reading

While results showed no main effect of time, $F(2, 132) = 1.05$, $p = .355$, $\eta^2_p = .02$, analyses did yield a significant interaction, $F(2, 132) = 3.16$, $p = .046$, $\eta^2_p = .05$ (see Figure 3). Table 2 reports the mean values and standard deviations by condition. Bonferroni post hoc tests revealed that performance in the workbook condition did not change from pre-test to post-test ($p = 1.00$) or to the follow-up test ($p = 1.00$). Performance in the TuinLECweb condition improved from pre-test to follow-up test ($p = .033$), but performance on the post-test did not differ from the pre-test ($p = .899$). Students in the TuinLECweb condition did not outperform students in the workbook condition on the post-test ($p = .786$). However, there was a trend towards significance in the difference between both groups on the follow-up test ($p = .091$).

Monitoring accuracy of non-search decisions

While the results showed no main effect of time, $F(2, 132) = 0.69$, $p = .502$, $\eta^2_p = .01$, analyses did yield a significant interaction, $F(2, 132) = 5.56$, $p = .005$, $\eta^2_p = .08$ (see Figure 4). Table 2 reports the mean values and standard deviations by condition. Bonferroni post hoc tests revealed that scores in the workbook condition did not change from pre-test to post-test ($p = 1.00$) or to the follow-up test ($p = .301$). Scores in the TuinLECweb condition improved from pre-test to follow-up ($p = .006$). In addition, there was a trend towards significance in the difference between the pre-test and post-test (p=.087).

As post hoc tests showed differences between both groups on the pre-test (p = .009), a new analysis was performed in which both groups were compared only at the follow-up test when using the pre-test gamma score as a covariate. The results showed significantly higher scores in the TuinLECweb group than in the workbook group, F(1, 65) = 4.773, p = .033, η^2_p =.068.

Figure 3. Performance in task-oriented reading by condition.

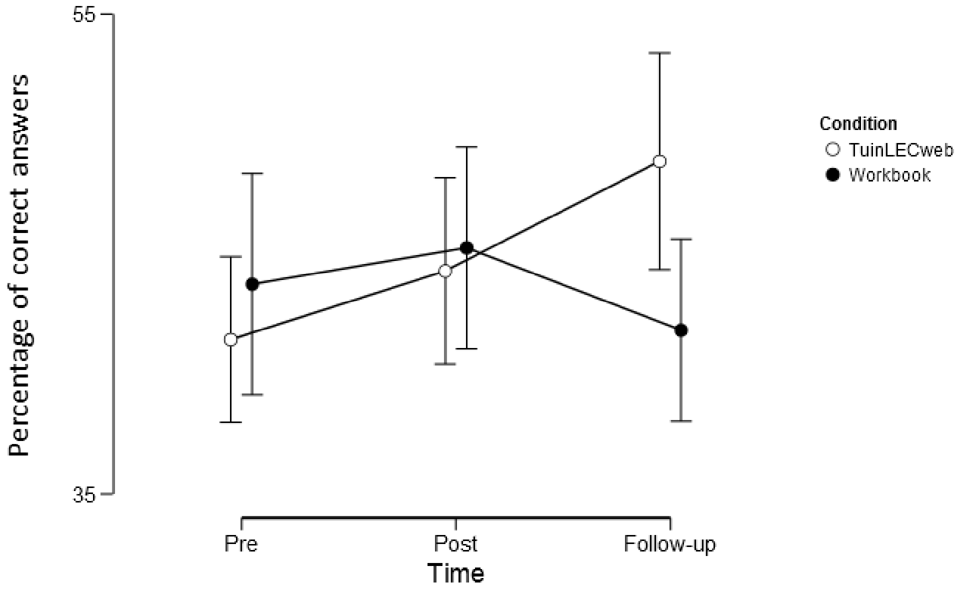


Figure 4. Monitoring accuracy of non-search decisions by condition.

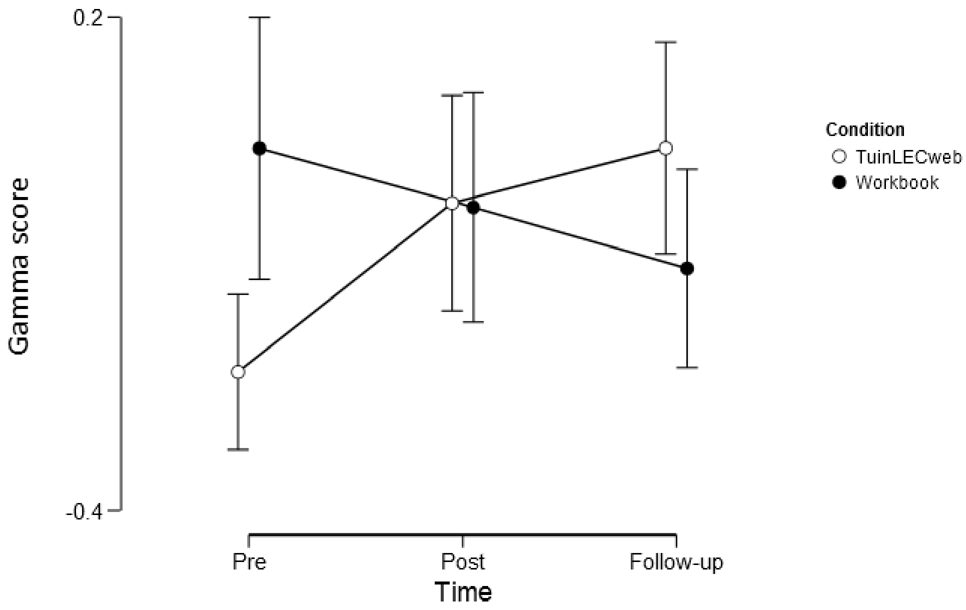


Table 2. Means and standard deviations (in parentheses) of task-oriented reading performance and monitoring accuracy of non-search decisions by condition.

	Performance			Monitoring accuracy of non-search decisions		
Comprehension level	Pre	Post	Follow-up	Pre	Post	Follow-up
TuinLECweb (*n* = 35)	41.43 (12.97)	44.29 (15.98)	48.86 (17.19)	-.23 (.32)	-.03 (.48)	.04 (.46)
Workbook (*n* = 33)	43.74 (13.56)	45.25 (12.96)	41.82 (16.56)	.04 (.49)	-.03 (.40)	-.11 (.43)

In summary, the results from Study 2 replicate findings in Study 1 regarding the effect of TuinLECweb in low-skilled comprehenders and show the superior efficacy of TuinLECweb compared to a traditional classroom intervention to improve low-skilled comprehenders' performance and monitoring accuracy of non-search decisions in task-oriented reading.

Discussion

Herein, we presented two studies that examined the effectiveness of a computer-based intervention called TuinLECweb, which teaches students to use monitoring and self-regulation strategies in the context of task-oriented reading (i.e., how to form a good representation of the text, how to build a good representation of the task, how to search the text, and how to self-regulate the need to search for information). The aim of Study 1 was to investigate (a) the differential effect of TuinLECweb to improve performance and monitoring accuracy of non-search decisions (i.e., how accurate a student is when he/she decided not to search the text before answering a question) in high-skilled and low-skilled comprehenders, and (b) the long-term effect of training with TuinLECweb in both groups. Study 2 was designed to (a) replicate the findings of Study 1 regarding the effect of TuinLECweb in low-skilled comprehenders, (b) compare the efficacy of TuinLECweb with a traditional classroom intervention to improve performance and monitoring accuracy of non-search decisions in a sample of low-skilled comprehenders, and (c) explore the long-term effects of both interventions. The effects of the intervention were determined based on the students' performance and monitoring accuracy of non-search decisions in a task-oriented reading test completed at two points in time: the day after the intervention and 2 weeks after the intervention.

In Study 1, we predicted that TuinLECweb training would be more beneficial for low-skilled comprehenders, who may lack appropriate strategies to be competent in task-oriented reading situations. Based on our prediction, the results suggest that the intervention with TuinLECweb was indeed beneficial for low-skilled comprehenders, as they improved their task-oriented reading performance and monitoring accuracy of non-search decisions after TuinLECweb. We further hypothesised that the effects of TuinLECweb would emerge in the post-test and be maintained in the follow-up test. The results partially confirmed our predictions, as the benefit of TuinLECweb for low-skilled comprehenders was non-significant in the post-test but significant at the follow-up test (i.e., after a 2-week delay without training). In addition, the results revealed that low-skilled comprehenders caught up to their skilled counterparts in monitoring accuracy of non-search decisions.

Based on our predictions, the results of Study 2 replicate the findings of Study 1 regarding the benefits of TuinLECweb in low-skilled comprehenders' performance and monitoring accuracy of non-search decisions. Our second hypothesis predicted that an intervention with TuinLECweb would be more effective than traditional classroom instruction in improving performance and accuracy of non-search decisions. In terms of performance, the results did not completely support our hypothesis, as the students in the TuinLECweb group did not significantly outperform the students in the workbook group. However, when we examined the strategic decisions, the results confirmed our hypothesis, as students in the TuinLECweb group showed better monitoring accuracy of non-search decisions than the students in the workbook group. Finally, we predicted that the effects of TuinLECweb would emerge in the follow-up test, as revealed in Study 1. The results confirmed our predictions, as the benefits of TuinLECweb were non-significant on the post-test but were significant on the follow-up test (i.e., after a 2-week delay without training).

Differential effects of TuinLECweb training

With regard to students' performance in Study 1, low-skilled comprehenders obtained greater gains in performance than their high-skilled counterparts. This is in accordance with prior research (e.g., McNamara, 2004; Potocki, Ecalle, & Magnan, 2015; Raphael & Pearson, 1985; Suggate, 2016). Comprehension skills play a role in the processes involved in question answering. Diverse factors are responsible for the poor comprehenders' lower performance on question answering, such as limited (e.g., lexical and morphosyntactic) and cognitive (e.g., working memory) abilities (e.g., Oakhill, Cain, & Bryant, 2003), or ineffective monitoring and control of their efforts to comprehend while reading (e.g., Oakhill, Hartt, & Samols, 2005). One explanation for our results is related to the metacognitive skills and the monitoring and self-regulation strategies trained in TuinLECweb, which might have partially compensated for limitations in basic processes among low-skilled comprehenders (Burton & Daneman, 2007; Walczyk, Marsiglia, Johns, & Bryan, 2004). Literature on self-regulated learning shows that metacognitive awareness of particular aspects of one's own cognitive functioning can enhance self-regulation (Zimmerman, 2001). That is, teaching low-skilled comprehenders what they need to know about themselves in order to manage their limitations leads to better monitoring and self-regulation of the efforts needed to solve a task.

Another explanation is related to the improvement in monitoring accuracy of non-search decisions exhibited by low-skilled comprehenders, who not only showed a greater effect of training, but also scored equivalently to their high-skilled counterparts. Previous research has shown that low-skilled comprehenders are not very good at calibrating their understanding of the text (Dunlosky & Lipko, 2007; Maki et al., 2005) and usually fail to give the right answer when they decide not to search, which indicates poor monitoring accuracy (Vidal-Abarca et al., 2010). The findings of our study indicate that low-skilled comprehenders can improve their monitoring skills by means of strategy instruction and formative feedback. TuinLECweb provides instruction in monitoring and self-regulation and makes use of adaptive and formative feedback focused on students' strategic search decisions that has been shown to be effective in improving strategic decisions (Llorens et al., 2014). The virtual agents scaffold students' metacognition by asking them strategic questions while the students solve a task. First, TuinLECweb prompts students to judge how sure they are of performing the task correctly before searching the text. After that, they are asked to search the text to ensure they have the correct answer. Finally, they are asked to indicate if their first judgment was or was not accurate based on the search result. When students answer the questions on their own, they receive formative feedback that is adapted to their performance in relation to their search decisions. The results show that scaffolding strategies used to assess whether one possesses the necessary knowledge to answer the question improves monitoring skills of low-skilled comprehenders, leading them to accurately self-regulate their search decisions..

In accordance with previous studies (e.g., McGee & Johnson, 2003; Suggate, 2016), high-skilled comprehenders were not expected to obtain important gains from TuinLECweb in performance or monitoring accuracy. An explanation for this result is that high-skilled comprehenders are more efficient in task-oriented reading situations, either due to greater metacognitive knowledge or to strategy use (e.g., Cataldo & Oakhill, 2000; Vidal-Abarca et al., 2010).

The findings from Study 2, where only low-skilled comprehenders participated, also reinforce the results of Study 1 regarding the benefits of TuinLECweb for low-skilled comprehenders in terms of performance and monitoring accuracy of non-search decisions in task-oriented reading situations.

Long-term effects of TuinLECweb training

All students completed a post-test and a 2-week follow-up in both Study 1 and Study 2. Our results showed that the effects of TuinLECweb for low-skilled comprehenders did not emerge immediately after the intervention, but rather after a 2-week delay without training.

Although few studies have addressed issues of long-term maintenance of strategy use (National Reading Panel, 2000), recent studies have found similar results. For instance, a recent meta-analysis (Suggate, 2016) revealed that skilled readers seemed to benefit the least from reading interventions, especially at follow-up, whereas low-skilled readers showed a greater retention of the intervention effect. These findings are encouraging because they suggest that low-skilled comprehenders remember and use the strategies beyond the time of training.

One factor that may account for the lack of significant effects on the immediate post-test is that the duration of the intervention was not long enough for low-skilled comprehenders to develop their strategic approach into automated skills (Afflerbach, Pearson, & Paris, 2008). Low-skilled comprehenders may need more time and practice to be able to adequately apply the learned knowledge and skills. Although students did not practice with TuinLECweb after finishing the training, they might have used the strategies in other contexts during the 2 weeks without training, making it possible to routinize their monitoring skills.

TuinLECweb instruction over classroom instruction

In Study 2, the effectiveness of TuinLECweb training was compared with a traditional teaching program in a sample of low-skilled comprehenders. The traditional teaching program simulated typical classroom comprehension instruction consisting of a workbook with texts and comprehension activities (Ness, 2011), but it did not provide instruction in monitoring and self-regulation strategies or adaptive formative feedback. The results for performance showed that differences between the TuinLECweb group and workbook group were in the predicted direction on the follow-up test, as students in the TuinLECweb group showed a non-significant higher performance than students in the workbook group. The results for monitoring accuracy of non-search decisions reveal that TuinLECweb training improves monitoring skills over traditional classroom instruction. These findings reinforce some of the acknowledged results in the current literature on the effectiveness of computer-based interventions to improve learning (e.g., Tamim et al., 2011; VanLehn, 2011). For example, the meta-analysis of Ma et al. (2014) revealed that the use of ITSs was associated with greater achievement in comparison with non-ITS computer-based instruction, teacher-led, large-group instruction, and textbooks or workbooks.

Some explanations for these results might be related to the advantages that the ITSs offer over traditional teaching methods. Specifically, the effectiveness of computer-based instruction has been mainly attributed to the immediacy of feedback and its adaption to the specific student’s response (e.g., Azevedo & Bernard, 1995). TuinLECweb traces students’ strategic behaviour and generates adaptive formative feedback, which is adapted not only to the students’ performance but also to their strategy use. Related to that, a recent study (Llorens et al., 2014) showed the effectiveness of providing adaptive formative feedback focused on students’ strategic decisions to improve performance (i.e., when and what information to search), search decisions and use of relevant information to answer questions in task-oriented reading. This study showed that this kind of feedback was more effective than feedback that only focused on the correctness of the students’ answers.

Limitations and future directions

The present studies have some limitations. The first one is related to the absence of a control group in Study 1, a limitation that was amended in Study 2. Second, the time between the post-test and the follow-up test in both studies (2 weeks) was relatively short. Hence, further research is needed to analyse the effects of TuinLECweb in the long-term, for example, six months after the intervention. Third, no other individual characteristics (e.g., motivation, engagement, strategic knowledge, and self-efficacy) besides comprehension skills were considered. Students with comprehension difficulties do not form a homogeneous group (e.g., Cain & Oakhill, 2006); consequently, further research should examine in greater detail the differential impact of TuinLECweb intervention according to other student characteristics besides their comprehension skills in order to identify the student profile that could most benefit from TuinLECweb. Finally, TuinLECweb is a first step in providing students with initial skills to monitor and self-regulate their learning. However, an isolated intervention with TuinLECweb may not be enough for students to deal with the amount of reading tasks they will encounter in their real lives. Because of that, systematic strategy instruction provided by teachers after TuinLECweb may help students to enhance their self-regulation skills.

Conclusion

Our results identify several important considerations for education professionals interested in implementing instruction programs to improve task-oriented reading skills. The present studies demonstrated that low-skilled comprehenders' performance and monitoring accuracy in task-oriented reading can be improved substantially by teaching them how to use monitoring and self-regulation strategies through an ITS called TuinLECweb. In addition, this study confirmed that low-skilled comprehenders use the strategies learned beyond the time of training. Finally, our results also provide arguments in favour of using computer-assisted programs in strategy instruction, as they show the advantages of TuinLECweb training over traditional classroom instruction to improve monitoring and self-regulation skills of low-skilled comprehenders.

These conclusions could also be extended to a field as broad as that of self-regulated learning. The learning process involves making continual assessments and decisions, such as what should be studied deeply, whether learning has been achieved, etc. Becoming an effective learner (as becoming an effective task solver) requires the application of general metacognitive strategies which enable the learner to accurately monitor and regulate the learning process (Boekaerts, 1999; Winne, 2001). TuinLECweb could serve as a first step in acquiring the necessary skills to become a self-regulated learner.

To conclude, according to the Programme for International Student Assessment (PISA; OECD, 2014), approximately 20% of Spanish students have trouble understanding and using documents to respond to questions 2 years after finishing primary school. Thus, earlier training in task-oriented reading strategies, such as that provided in the present study through TuinLECweb, could help low-skilled comprehenders overcome comprehension deficits when using texts to answer questions and could help reduce the number of students diagnosed as poor comprehenders in later grades of primary school. Hence, the use of ITSs such as TuinLECweb may be considered by teachers as a supportive tool for enhancing strategy instruction in the classroom.

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