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Effects of two computer-based interventions on reading comprehension: Does strategy instruction matter?

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ABSTRACT

Managing text information to answer questions is one of the most frequent reading activities. These reading situations, called task-oriented reading, are challenging for students since they require specific skills that extend beyond basic reading comprehension skills. This is especially-pronounced when deep comprehension is required. Although many computer-based interventions have focused on teaching strategies to foster text comprehension, the role of strategy instruction in task-oriented reading has not been examined. In this study, we aim to ascertain the efficacy of an intervention based on task-oriented reading strategy instruction (TuinLECweb), in both text-base and situation model levels of comprehension, comparing it with training based on question-answering practice (AutoLEC). Moreover, we analyzed students' use of the instructional components and resources of the programs and the relationship to their efficacy. One hundred and thirty pupils attending sixth grade participated in this experimental pre-post study. The intervention comprised eight sessions in which students followed the training on their computers in the classroom. Results show that participants in both conditions raised their reading scores; however, while students in AutoLEC training obtained higher textbase scores, students in the TuinLECweb condition improved their situation model performance. Besides, gain in reading comprehension was not related to either instructional components or resources. These findings highlight the key role of strategy instruction in fostering deep comprehension when employing computer-based interventions in task-oriented reading. Moreover, these results point out the needto analyze how students manage the instructional aids offered to them.

1. Introduction

Managing textual information to answer questions and having them corrected is one of the most frequent reading activities in schools (Ness, 2011). However, many students struggle to successfully deal with this task, especially when the information is not explicit in the text. In these scenarios, usually called task-oriented reading (Vidal-Abarca et al., 2010), students need to apply strategies to comprehend the text but also the task demands, and make a series of additional strategic decisions, such as when to search for text information or which information reread to answer a given question (Guthrie & Kirsch, 1987; Rouet, 2006).

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Classic theories and empirical research on reading have focused on how to build an overall understanding of a text (Filderman et al., 2021), and effective intelligent tutoring systems (ITSs), based on strategy instruction, have even been implemented (Xu et al., 2019). Nonetheless, less is known about how to teach students the additional skills needed to answer questions from texts, and consequently, computer-based interventions have scarcely been developed. A Spanish ITS on task-oriented reading has been successfully tested (Serrano et al., 2018), but the role of strategy instruction in this type of scenario has not been examined.

In this study, our purpose is to ascertain if, as literature on reading comprehension suggests, students need specific strategy instruction to obtain a real improvement in task-oriented reading, or just practising question-answering -as traditionally done in classrooms-would be enough. To do so, we recruited students from the last year of primary education in Spain, since this is when citizens' basic reading skills should have been acquired and the transition from learning-to-read to reading-to-learn is expected to be accomplished (Goldman et al., 2010).

1.1. Reading literacy and task-oriented reading

In everyday life, we read a wide variety of textual information with an increasing range of goals and purposes (White et al., 2010). For this reason, the current conception of reading literacy highlights the need for considering the specific reader's purpose when reading a text, besides the processes required to form a mental representation of the text (Britt et al., 2017; Snow, 2002). In task-oriented reading, readers handle one or more texts while knowing in advance that they have to perform a task for which the texts are a crucial source of information (Vidal-Abarca et al., 2010). This framework has been used in international reading assessment programs like PISA (OECD, 2018) or PIRLS (Mullis & Martin, 2019). Both programs use a variety of texts (narrative, procedural, expository, etc.) that are representative of those students may read in different situations - not linked to a specific school subject (but with contents from natural and social sciences, for example)-, and different types of questions.

In task-oriented reading situations, the questions guide the reader's mental activity and the level of comprehension needed to answer. Some questions require the reader to retrieve an idea or specific information from the text, with superficial comprehension being enough, whereas others are more demanding and imply connecting different parts of the text and/or making inferences, requiring a deeper comprehension (Tawfik et al., 2020). Thus, it is commonly accepted in the scientific literature that the mental representation generated when reading has at least two levels (van Dijk & Kintsch, 1983): textbase and situation model. The first level contains explicit textual information, requires local inferences to connect contiguous sentences, and is elaborated more or less automatically. The second level allows the generation of implicit information by means of more complex inferences that integrate information that appears in different parts of the texts or that relate explicit information to the reader's previous knowledge (McNamara, 2021; Smith, Snow, Serry, & Hammond, 2021). Reading comprehension complexity stems from this second level, from the cognitive processes to be carried out to achieve a deeper representation of the text, which are often non-automatic and requiere comprehension strategies that are reflective, intentional, and purposeful by nature.

Additionally, effectively making use of texts to answer comprehension questions demands strategies and skills that extend beyond those required to build a representation of the text. That is, the reader needs to build a reading strategy and make a series of self-regulation decisions regarding when to read, which information to read, and how to read it (Cataldo & Oakhill, 2000; Rouet, 2006; Sun et al., 2021). The RESOLV model (Britt et al., 2017) offers an approach for task-oriented reading. This model begins with the comprehension of the task demands and the construction of the task model, which will guide the iterative processes between the question and the text. That is, the task model will determine whether the question can be answered without going back to the text or a rereading is needed. Therefore, readers need to constantly assess the relevance of the information having their goal in mind, which will modulate the allocation of cognitive resources to specific text segments. In addition, readers also have to decide when they have all the necessary information to provide an adequate response. These decisions, which are mainly based on metacognitive processes, play a fundamental role in such an interactive process and have an impact on the final success of the task (Gil et al., 2015; Vidal-Abarca et al., 2011). However, many students, especially the youngest and lowest-skilled readers, have trouble dealing with these tasks (Cataldo & Oakhill, 2000; Cerdán et al., 2011; Rouet & Coutelet, 2008). Moreover, those processes require a certain level of engagement and effort, so readers have to maintain their motivation (Orellana et al., 2020; Wigfield et al., 2016). Since these cognitive and metacognitive processes are not usually automatic and demand the individual's commitment, students often need guidance and support during the task-oriented reading process.

1.2. Teaching reading literacy in the classroom

Based on classic theories of reading comprehension, extensive research has been conducted on what and how to teach students to help them construct a mental representation of the text; however, little is known about which specific task-oriented reading skills to teach and how.

Regarding what to teach to help build a mental representation of a text, evidence-based teaching practices highlight comprehension strategies (e.g. question generation, summarization, clarification, and prediction) (Afflerbach et al., 2020, pp. 98–118; Filderman et al., 2021). In regard to task-oriented reading, Rouet (2006)'s- model suggests that the strategies needed to answer questions from texts include those related to examining the question demands, self-regulating the search decision (i.e., when to reread the text) and the search process (i.e., which piece of information to read).

With respect to how to teach comprehension strategies, two elements have been shown to be effective: 1) Strategy instruction, based on modelling, explicit teaching and guided and deliberate practice (Filderman et al., 2021; Joseph et al., 2021; Pearson & Dole, 1987); 2) Feedback (Golke et al., 2015). Thus, Okkinga et al. (2018) found in their meta-analysis that modelling was a relevant didactic principle to improve students' strategic ability. Therefore, effective teachers provide a direct explanation of what, how, why, and when a comprehension strategy should be used, but also by modelling or demonstrating how to apply those strategies and guiding the student's practice. In this step, both teachers and students work together in applying the strategies to gradually and slowly release the responsibility to the student (Afflerbach et al., 2020, pp. 98–118; Duke & Pearson, 2002, pp. 205–242; Rosenshine & Meister, 1994).

In addition, research on reading comprehension is consistent in reporting the benefits of providing feedback (Golke et al., 2015; Murphy, 2010; National Reading Panel, 2000). The literature on feedback in educational contexts usually differentiates between three main types, according to their content (Shute, 2008): Knowledge of Results (or KR), Knowledge of Correct Response (KCR), and Elaborated Feedback (EF). Whereas KR messages only provide information about the correctness or incorrectness of the student's responses, KCR messages include the correct solution to the task, and EF messages offer information about the accuracy of the student's answer, such as explanations or hints. Research on the effects of feedback on learning in general (and on reading comprehension in particular) is inconsistent and the conclusions differ depending on multiple variables. However, results from a meta-analysis found that, in computer based-learning environments, EF produced larger effect sizes (0.49) than KCR (0.32), or KR (0.05), especially in higher-order learning tasks (van der Kleij et al., 2015). If we focus on reading comprehension, another meta-analysis concluded that EF and KCR feedback were more effective in learning from texts than KR (Swart et al., 2019).

Finally, regarding instruction on task-oriented reading, research on how to teach it is much scarcer but seems to be in the same direction. One of the few interventions following this approach is the one of Raphael and colleagues, who successfully trained question-answering skills in fifth graders using modelling and explicit teaching on the relationship between different types of comprehension questions and location of the answers (Raphael & Au, 2005; Raphael & McKinney, 1983). Similarly, other authors explicitly teach students to search for information in textbooks using headings as locational aids (Kobasigawa et al., 1988) or provide strategy instruction to locate answers and monitor their success (Symons et al., 2001), obtaining good results. More recent studies assessing the effect of providing feedback in task-oriented reading concluded that informing students of the correct strategy was effective in improving performance and strategic decisions, leading them to increase their search decisions and their focus on relevant information when they received EF (Llorens et al., 2014, 2016). Finally, Cerdán et al. (2021) improved students' performance in question-answering by fostering the construction of an adequate task model.

Despite scientific knowledge, the most usual practice in classrooms is merely to ask students to answer comprehension questions and have them corrected (Ness, 2011; Wijekumar et al., 2021); that is, students usually only receive general KR and KCR feedback messages. Although this practice makes some improvement in students' reading comprehension, teachers often rely on textbook texts and questions to this end, ignoring the fact that this may not be the best choice for teaching reading comprehension (Wijekumar et al., 2021). Thus, Spanish textbooks often include texts that are designed by the textbook authors, which reduces students' exposure to authentic texts, and their variety is limited (Garcia-Pitxer, 2019). Regarding the activities that follow the texts, they have been found to be mainly of a low cognitive level, with many of them being answered by identifying explicit information in the text (Ortega-Sánchez et al., 2019; Sepúlveda et al., 2020; Wijekumar et al., 2021).

In short, there is still a great distance between what is proposed in the scientific literature and what too often happens in the classroom, at least in Spain. One of the reasons may be related to logistical constraints, which make it impossible for a single teacher to carry out a complete evidence-based strategy instruction in a typical classroom setting with a large number of students. In this regard, technology has emerged as a means to overcome these problems.

1.3. Using technology to scaffold reading instruction

As we have addressed, the development and improvement of new complex skills, such as reading proficiency skills, usually requires explicit instruction combined with feedback and also a significant amount of practice over an extended period of time (Duke & Pearson, 2002, pp. 205–242). In this regard, computer-based systems offer distinct advantages over traditional classroom teaching. First, they may provide the instruction needed and greater opportunities to practice, as well as a broader set of examples than a student would normally be exposed to in the classroom (Martin et al., 2007; McNamara, 2010). Second, technology allows students to have control over the learning process in terms of pacing, sequencing, instructional content (e.g., on-demand help), or feedback, which can also increase student engagement and learning expectations (McNamara, 2010; Milheim & Martin, 1991). Another advantage of computer-based systems that explains their efficacy is the possibility of accurately recording learners' actions and generating timely and tailored feedback (Azevedo & Bernard, 1995; Morgan et al., 2020). Finally, there is also a motivational element that supports the use of technology for learning (Vogel et al., 2006). Since fifth- and sixth-grade students usually prefer to read on-screen (Golan et al., 2018), using computers seems more motivating for children than reading with print documents.

All these opportunities that technology offers have fostered the development of computer-based systems to teach and train complex skills. Thus, in the last two decades, strategy instruction through computer-based systems have been implemented (Jamshidifarsani et al., 2019; Lan et al., 2014; Ponce et al., 2012; ter Beek et al., 2018; Xu et al., 2019). In the field of reading comprehension, technology has also shown the potential to implement sophisticated tutoring strategies (e.g., modelling and scaffolding) through Intelligent Tutoring Systems (ITSs). A recent meta-analysis has found that ITSs for reading comprehension produce larger effects than traditional instruction and other educational applications (Xu et al., 2019). Softwares like iSTART (McNamara et al., 2006), 3D-Readers (Johnson-Glenberg, 2005, 2007), or ITSS (Wijekumar et al., 2012, 2017), for example, have proved their efficacy. These programs include explicit instruction of cognitive and metacognitive strategies and extensive practice with expository or narrative texts. Some studies have shown that such sophisticated strategies, however, are rarely implemented by human tutors (Graesser et al., 2009).

In this study, we employed an ITS specially designed for training and teaching task-oriented reading skills to upper elementary and early middle school students: TuinLECweb (Vidal-Abarca et al., 2017). This program includes three evidence-based didactic principles previously addressed in the theoretical framework (modelling, explicit instruction, and guided practice) and two types of resources (EF and on-demand aids) distributed in an instruction phase and a practice phase (see a description of the program in the Method section).

1.4. Previous studies with TuinLECweb

Few studies have tested TuinLEC's efficacy to improve task-oriented reading and results vary depending on the study design, the sample, and the instruments employed. In a pilot study with a previous version of TuinLECweb (i.e., TuinLEC; Vidal-Abarca et al., 2014), half of a group of 25 sixth-graders was trained with TuinLEC out of school hours, whereas the other half acted as a control group and performed other activities on their own. The two groups were tested in reading comprehension before and after training using two different standardized tests (both developed by the same research team): TEC-e (Martínez et al., 2009) and CompLEC (Llorens et al., 2011). The study concluded that the trained group increased their reading comprehension skills over the control group (Vidal-Abarca et al., 2014).

Another study with the latest version of TuinLEC (i.e., TuinLECweb) (Serrano et al., 2018; Study 1) showed that the intervention primarily benefited low-skilled comprehenders (sixth- and seventh-graders), as they improved their performance two weeks after the intervention. Finally, in a third study (Serrano et al., 2018), 68 low-skilled comprehenders were trained either with TuinLECweb or with a traditional teaching program that simulated typical classroom comprehension instruction. It consisted of a workbook with texts and comprehension activities that students completed on their own. Results showed the superior efficacy of TuinLECweb compared with a traditional classroom intervention to improve low-skilled comprehenders' monitoring skills and performance in task-oriented reading. In both studies, students were tested in reading comprehension using tests developed ad hoc by the authors.

Although the three studies conducted yielded positive results on the efficacy of this software to improve students' reading competence, more research is needed to ascertain what the efficacy of a task-oriented reading instruction relies on. First, the control group of the previous study (Serrano et al., 2018; Study 2) received an intervention in a paper-and-pencil format. This led us to question whether the results were due to the use of computers and practice with certain texts and questions or to the didactic principles and resources of TuinLECweb. Second, the latest version of TuinLECweb has not been tested using a standardized comprehension test. As known, effect sizes are significantly larger for researcher-developed instruments than for standardized tests (Okkinga et al., 2018). Third, none of these studies have analyzed the students' use of the instructional components and resources of TuinLECweb and the role they have in students' outcomes. TuinLECweb collects data on the time each student takes to complete each of the modules, as well as the aids used and the feedback reviewed in the practice phase. These data allow us to know the specific use that they make of these TuinLECweb components and resources. Although learning analytics research is extensive, especially in open learning environments and in higher education (Bernacki et al., 2012; Lust et al., 2013; Saint et al., 2022), few reading comprehension ITSs have explored how students use their resources and whether they contribute to learning (Snow et al., 2014; 2015). While learning gains are the key outcome for ITSs, other aspects, such as the time spent in the intervention (Godwin et al., 2021) and the students' use of the instructional elements, may allow us to understand why an ITS works and how it can be improved.

1.5. The present study

Strategy instruction through TuinLECweb has already shown its efficacy for improving task-oriented reading outcomes in upper elementary and early middle school students. However, we wonder whether the improvement is due to the simple practice of question-answering with corrective feedback or to the evidence-based instructional elements and resources. That is, can students develop strategies to answer comprehension questions just by practicing question-answering and receiving corrective feedback, as they usually do in schools, or do they need strategy instruction, as research in reading comprehension suggests? Also, do they need the same type of instruction for improving the skills needed to answer textbase questions as to answer situation model questions? As far as we know, computer-based strategy instruction has not been compared to other training which resembles traditional classroom practices but supported by computers, so the impact of the motivational factor of reading on a screen is removed. Thus, the present study has two aims.

i) To ascertain the efficacy of an intervention based on task-oriented reading strategy instruction (TuinLECweb), in both textbase and situation model levels of comprehension, comparing it with training based on question-answering practice and corrective feedback (KR and KCR).

Table 1
Instructional components, resources and phases in each intervention.

Instructional component	Phase	TuinLECweb	AutoLEC
Instruction	1	Explicit instruction and modelling	–
Practice	1	Guided	Autonomous
	2	Autonomous	
Feedback	1 & 2	KR	
		KCR	
		EF	–
Aids	2	Search aids (binoculars and magnifying glasses) and question-demands aid (lifebuoy)	–

Note. KR = Knowledge of Results; KCR = Knowledge of Correct Response (KCR); EF = Elaborated Feedback.

ii) To explore the students' use of the instructional components and resources that the programs offer and their relationship to students' comprehension outcomes.

To address these objectives, we designed and implemented a "minimum" computer-based intervention that we called AutoLEC. AutoLEC was an ad-hoc training program designed for this study, which used all the texts and questions employed in TuinLECweb, plus two extra texts and 20 extra questions to match the time spent in each program. As in TuinLECweb, students answer the questions with the texts available. AutoLEC offers corrective feedback once the student has answered the questions, so the reader knows whether his/her answer was right or wrong (KR feedback) and which option was correct (KCR feedback) after the task is finished. Both programs were divided into two phases, with four modules in each phase: in TuinLECweb, phase 1 corresponded to instruction and phase 2 to practice; whereas in AutoLEC, both phases corresponded to practice. A comparison between the two interventions can be seen in Table 1.

The research questions were the following.

RQ1. - To what extent do students differ in task-oriented reading outcomes (textbase, situation model) following a strategy-based vs. a question-answering-based intervention?

RQ2. - How do students actually use the instructional components and resources of the interventions and what is the role of these elements in the improvement in reading comprehension (textbase, situation model)?

Based on the literature review, our hypotheses were the following. First, we expected students to improve their reading scores after following both interventions. Second, our prediction was that strategy instruction (TuinLECweb) would be more effective than just obtaining KR and KCR feedback after practicing question-answering (AutoLEC), as it contains a wider range of evidence-based instructional components and focuses on strategy instruction (Filderman et al., 2021). In particular, we expected strategy instruction (TuinLECweb) to be especially effective for deep comprehension questions since this comprehension level usually requires effortful reader-initiated processes that are mostly strategic, so they can be acquired through instruction and practice (van den Broek & Helder, 2017). Finally, we conducted exploratory analyses of the possible relationship between the students' use of the instructional components and resources of the interventions and participants' gain scores.

2. Method

2.1. Participants

One hundred and seventy-four students attending sixth grade were asked to participate in the study. They belonged to seven intact classes of three different schools from the north and the east region of Spain. Participants were randomly assigned to the conditions (TuinLECweb vs AutoLEC). Students with learning disabilities and those without parental consent were excluded from the dataset. Besides, students who did not complete at least six of the eight modules, or one of the comprehension tests (i.e., pretest/posttest) were also removed. After these exclusions, 130 students met all the requirements and remained part of the study (mean age: 11.33, SD = 0.54; 48.5% female). The final distribution between conditions includes 71 in TuinLECweb and 59 in AutoLEC.

As determined by a priori power analysis (G*Power 3; Faul et al., 2007) with alpha level and statistical power respectively set at 0.05 and 0.95, a 130-participant sample is appropriate to detect an interaction effect of time and condition on reading comprehension equal to a partial eta-squared of 0.03 (minimum necessary sample size = 108; taking into account the effect size found by means of a similar experimental design by Serrano et al., 2018).

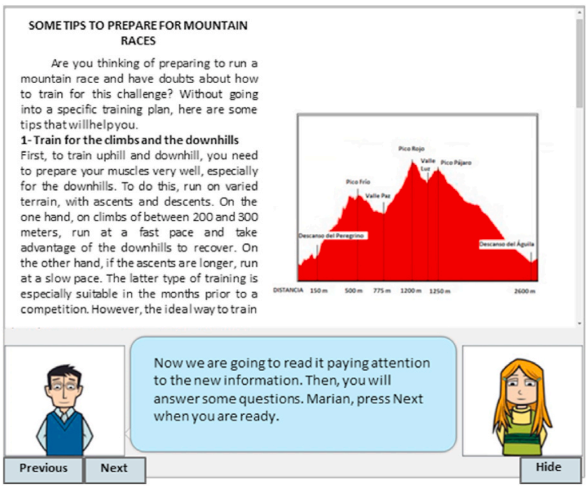

Fig. 1. Screenshot of instructional modules screen.

2.2. Materials

2.2.1. TuinLECweb's description

TuinLECweb is an intelligent tutoring system designed to teach reading comprehension skills from a task-oriented reading approach (Serrano et al., 2018; Vidal-Abarca et al., 2017). It includes explicit teaching and practice of task-oriented reading skills with adaptive feedback in a game-like environment. TuinLECweb includes a variety of texts and different types of questions to be answered with the text available, which are structured in eight modules divided into two phases, one for explicit strategy instruction and guided practice (i.e., instructional phase: modules 1 to 4), and another for practice (i.e., practice phase: modules 5 to 8).

The strategy instruction is conducted through modelling, explicit teaching, and guided practice via dialogs between two animated agents: Ramiro, the teacher, and Lue, the student (see Fig. 1 for a screenshot of the instructional modules screen). The modules devoted to strategy instruction correspond to the main stages of task-oriented reading and provide strategies to be successful at every stage (see Appendix for an overview). The strategies cover: strategies for building a mental scheme of the text contents (e.g., noticing text organization), strategies for examining the question demands (e.g., identifying the process required to answer it), strategies for self-regulating the search process (e.g., locating relevant information depending on task demands), and strategies for self-regulating the search decision (e.g., monitoring the need for text information). The virtual teacher presents texts and questions, explains the strategies, and provides feedback, whereas the virtual student acts as a model, not only of appropriate but also of incorrect strategies. The student is involved in the modules by answering questions and performing a variety of tasks together with the virtual student. However, at the end of every module, the student's participation increases by practicing the strategies more independently.

In each module, the strategies are taught and practiced using one or two texts and between 14 and 21 activities. The texts are interesting and challenging for students; they are different from those found in textbooks and more similar to texts that can be found in real life. Their length ranges from 300 to 600 words and they are of different formats, both continuous and non-continuous. Regarding the activities, TuinLECweb displays multiple-choice questions, selecting keywords, pairing tasks, and selecting textual information. Multiple-choice content questions are of two types: textbase and inferential, with the latter being the most numerous.

Throughout each module of the instructional phase (modules 1 to 4), the virtual teacher provides feedback not only referring to the right or wrong answer, but also to the strategy involved in the answering process. Thus, the feedback always includes explanations for correct and incorrect answers, information about the type of errors based on the strategies involved, and advice on effective strategies for the next questions.

After the instructional phase, students are trained with extensive deliberate practice of the strategies learned by reading texts and answering questions with the text available. Each practice module consists of two texts and 14 multiple-choice questions. In these modules, the interface changes, and virtual agents are not present. Instead, students are provided with three types of help tools to deal with the questions and receive formative feedback after answering each question. Two of the help tools (i.e., binoculars and magnifying glass) are aimed at helping students locate the parts of the text that contain information relevant to answering the questions, whereas the lifebuoy intends to assist in identifying the question demands and the process required to answer them (see Fig. 2). Students can use the help tools at will, but it has a cost in points.

As in the instructional phase, students receive feedback after answering each question. This feedback is presented in different modes. Firstly, the correct answer choice is indicated by a green tick; secondly, the relevant information for the question is highlighted in the text; and finally, students receive written elaborated and adaptive feedback (EF). It depends on their performance, the use of help tools, the time devoted to checking the relevant information after answering the question, and the strategies implemented (e.g., search the text). It also includes some advice on how to proceed with the following questions and acts as a motivational element (see Fig. 3).

In both instructional and practice phases, students earn points with every correct answer which turn into stars at the end of each module. This feature seeks to maintain motivation and commitment to the task.

2.2.2. Intervention materials

Both training programs employed the same texts and the same questions, those which belonged to TuinLECweb. It used 14 texts containing narrative, expository and discontinuous texts (see Appendix). There were 92 questions about text content (23 textbase and

Fig. 2. Screenshot of binoculars help used in a question.

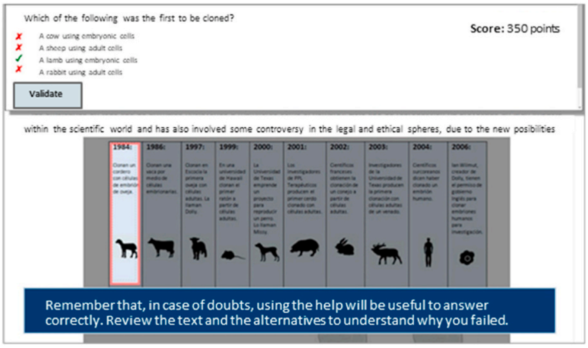

Fig. 3. Different types of feedback presented in distinct modes.

79 situation model). One text with 10 questions was added to both modules 1 and 2 in the AutoLEC condition in order to match the time spent in each program.

2.2.3. Assessment materials

For the pretest and posttest we employed an adapted version of a Spanish standardized reading comprehension test, ECOMPLEC (León et al., 2012), which follows the current conceptual frameworks of reading literacy (OECD, 2018) and provides measures for the two levels of representation: textbase and situation model. It shows adequate validity and reliability indexes (Fisher's z = 0.88). It contains one narrative text and one expositive text and 42 questions (22 narrative, 20 expository; 21 textbase, 21 situation model). The texts are available when answering the questions.

2.3. 3. measures

Regarding the use of the instructional components of the TuinLECweb intervention, we operationalize the variables as follows.

- *Total minutes in the intervention:* Total minutes spent in the program.
- *Minutes in phase 1*: Total minutes spent in the first four modules.
- *Minutes in phase 2*: Total minutes spent in the last four modules.
- *Use of aids:* Percentage of students that use at least one aid once.
- *Number of aids*: Number of questions in which students used any of the aids.
- *Use of EF:* Percentage of students that reviewed the EF at least once.
- *Number of EF review*:s Numbers of questions in which the students decided to use the strategy of reviewing the feedback after answering.

In AutoLEC, only the variables regarding time were computed.

With respect to reading comprehension pretest and posttest, four measurements were computed:

Textbase score: Percentage of correct answers in textbase questions of the comprehension test.

Situation model score: Percentage of correct answers in situation model questions of the comprehension test.

Textbase gain score: Textbase score in the postest minus textbase score in the pretest.

Situation model gain score: Situation model score in the postest minus situation model score in the pretest.

2.4. Procedure

This study employed a pretest/posttest experimental design with a comparison group. Participants were randomly assigned to AutoLEC or TuinLECweb conditions within each class. The intervention comprised eight 50-min sessions which were carried out over approximately two months in the last trimester of the school year. Students followed the intervention on their computers twice a week in the lab, always in the presence of their teacher, as a part of their regular lessons. One week prior to the beginning of the training, the authors explained their participation in the study to the pupils and, assisted by the teachers, collected the pretest measures. Two weeks after finishing the program, the posttest measures were taken in the same way.

Regarding the ethical commitment, we followed the guidance presented in the Research and Publication section of the Ethical Principles of Psychologists and Code of Conduct (APA, 2016). Before the training, we sent an informed consent form to all the families of sixth-grade students. Some parents requested more information on the study but only less than three percent of them refused to participate. At the end of the school year, we returned a brief report on the class performance to each teacher and to the school principal.

2.5. Data analyses

All the statistical analyses were conducted using the SPSS for Windows (version 26).

In order to answer the research questions, we obtained descriptive results and performed a *t*-test. Since significant differences were found between conditions in the pretest and in the minutes spent in phase 1, we considered them as covariables in subsequent analysis. To address RQ1 we conducted two analyses: a three-way mixed analysis of covariance (ANCOVA) to analyze the change in both comprehension levels (textbase and situation model) after the interventions (TuinLEC and AutoLEC) and two one-way ANCOVA to analyze the differences between conditions in the posttest measures after adjusting for pretest measures. Bonferroni adjustment was applied to each of the separate ANOVA. With respect to RQ2, we computed a learning gain variable to perform correlation analyses.

3. Results

Table 2 reports the mean values and standard deviations of the variables by condition.

Assumptions were met for each test. Unpaired Student's t-tests showed that differences between conditions before the intervention were significant in the textbase score ($p = .01$) but not in the situation model score ($p = .46$), so students in the TuinLECweb group were better than students in AutoLEC at textbase questions but not at deep comprehension. Regarding the minutes spent in the programs, significant differences between conditions were found in the total minutes ($p < .001$) and in phase 1 ($p < .001$), but not in phase 2 ($p = .81$). For that reason, we considered minutes in phase 1 in RQ1.

3.1. Research question 1

To examine whether students improve their scores after the interventions on the two levels of a text understanding, i.e., textbase and situation model, we conducted a three-way mixed ANCOVA, with condition (TuinLECweb, AutoLEC) as a between-participants variable, time (pretest, posttest) and question type (textbase, situation model) as within-participants variables, and minutes in phase 1 as covariate. Results showed a non significant main effect of time ($F < 1$, $p = .75$, $\eta_p^2 = .001$), and non-significant interaction effects between condition and time ($F < 1$, $p = .80$, $\eta_p^2 = .001$), condition and type of question ($F(1, 128) = 1.27$, $p = .26$, $\eta_p^2 = .010$), or type of question and time ($F < 1$, $p = .36$, $\eta_p^2 = .01$). However, there was a significant interaction effect between the time, the question type, and the condition, $F(1, 128) = 8.63$, $p = .004$, $\eta_p^2 = .064$ (see Fig. 4). Post hoc Bonferroni-corrected pairwise comparisons indicated that students in TuinLECweb condition improved their scores in situation model questions from pretest to posttest ($p < .001$, $d = 0.451$), whereas scores in textbase questions showed no significant differences between pretest and posttest ($p = .88$, $d = 0.018$). In contrast, students in AutoLEC significantly improved their scores in textbase questions from pretest to posttest ($p = .03$, $d = 0.305$), but not the scores of the situation model ones ($p = .69$, $d = 0.052$). The interaction of the covariate, minutes in phase 1, with the factor "time" ($p = .50$) and the factor "question type" ($p = .50$) was not significant, neither was the triple interaction ($p = .53$).

Textbase questions Situation model questions.

In order to analyze the differences between conditions in the posttest measures after adjusting for pretest measures, two ANCOVAs were conducted with condition as a between-participants variable, pretest score and minutes in phase 1 as covariates, and posttest score in each type of question as dependent variables. Results showed no significant differences in textbase questions' scores between TuinLECweb and AutoLEC after the intervention, $F(1, 127) = 0.30$, $p = .59$, $\eta_p^2 = .002$. However, students in TuinLECweb condition

Table 2
Mean values and standard deviations for TuinLECweb (TW) and AutoLEC (AL) and mean contrast, by condition in all the measures.

Measure	TuinLECweb ($n = 71$)	AutoLEC ($n = 59$)	Range
	M (SD)	M (SD)	
Score by type of question			
Textbase (pretest)	84.00 (9.41)	79.11 (12.32)	0–100
Textbase (posttest)	84.25 (8.96)	81.99 (10.13)	0–100
Situation model (pretest)	68.57 (10.55)	70.15 (13.92)	0–100
Situation model (posttest)	73.69 (10.89)	70.66 (13.35)	0–100
Textbase gain score	0.25 (10.54)	2.87 (11.03)	0–100
Situation model gain score	5.12 (10.64)	0.51 (9.63)	0–100
Students' behaviour in the intervention			
Total minutes	209.79 (55.75)	165.04 (39.27)	TW: 91.80–377.16 AL: 101.67–291.17
Minutes in phase 1	139.02 (45.75)	93.50 (27.42)	TW: 29.18–261.76 AL: 38.90–168.22
Minutes in phase 2	70.77 (19.30)	71.54 (17.20)	TW: 18.87–118.99 AL: 42.90–130.57
Use of aids	78,9%	–	0–100%
Number of aids	9.70 (12.20)	–	0–56
Use of EF	99%	–	0–100%
Number of EF reviews	8.21 (6.23)	–	0–56

Note. EF = Elaborated Feedback.

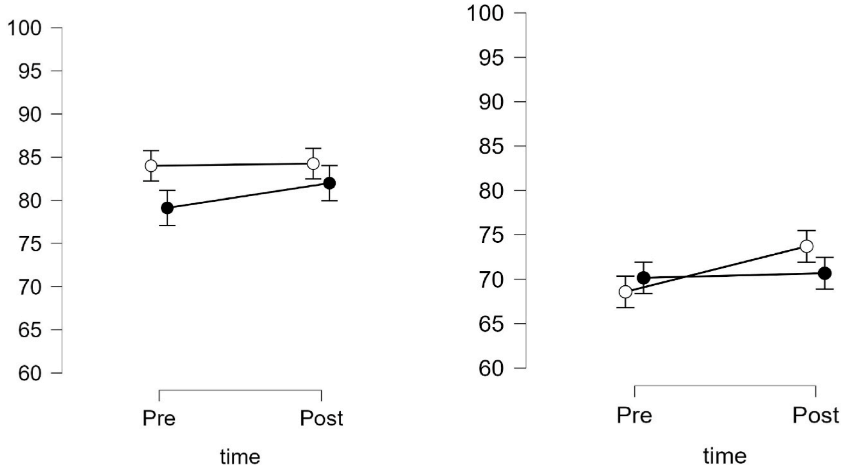

Fig. 4. Mean values for TuinLECweb (white) and AutoLEC (black) group in performance on the pretest and posttest (textbase questions on the left; situation model questions on the right). Error bars represent the 95% confidence interval for the means.

outperformed AutoLEC participants in the situation model questions after the intervention, F (1, 127) = 3.98, p = .048, η_p^2 = .031. The effect of the covariate, minutes in phase 1, was not significant in textbase (p = .14) or in situation model (p = .81) levels of comprehension. The covariate pretest score was significantly related to the posttest score in both, textbase (F (1, 126) = 31.05, p < .001, η_p^2 = .198) and situation model (F = 90.57, p < .001, η_p^2 = .418).

3.2. Research question 2

As can be seen in Table 2, students spent more minutes in phase 1 of TuinLECweb (instructional phase) than in phase 1 of AutoLEC (autonomous practice), t(117.17) = 7.01, p < .001), but the minutes spent in phase 2 did not differ between interventions, t(128) = −0.24, p = .81. In addition, participants in TuinLECweb employed the aids in a few questions, although they used them at least once. The same occurred with the feedback: they reviewed it in a few questions, but almost all of them did so at least once.

In order to examine whether the use of instructional components and resources of AutoLEC and TuinLECweb were related to learning gains in textbase and situation model, correlation analyses were performed (Table 3). No significant correlations were found between learning gains and minutes spent in the programs, either textbase or situation model level. Neither the aids nor the EF review was related to learning gains.

4. Discussion

4.1. General discussion

This study had two objectives: to ascertain the efficacy of an intervention based on task-oriented reading strategy instruction provided by an ITS (TuinLECweb) comparing it to other computer-based instruction on question-answering practice, more similar to a traditional classroom instruction (AutoLEC), and to analyze students' use of the instructional components and resources and their relationship to the students' task-oriented reading outcomes.

It is worth remembering that previous research had already proved the efficacy of TuinLECweb, since Serrano et al. (2018) used

Table 3
Correlations between gain scores and use of instructional components and resources in both interventions.

	1	2	3	4	5	6	7	8
Gain scores								
1. Textbase	–	.06	−.05	.22	–	–	–	–
2. Situation model	.27*	–	−.11	−.04	–	–	–	–
Students' behaviour in the intervention								
3. Minutes in phase 1	.15	.07	–	.52**	–	–	–	–
4. Minutes in phase 2	.07	.04	.36**	–	–	–	–	–
5. Use of aids	−.02	−.06	.03	.15	–	–	–	–
6. Number of aids	.07	−.08	.13	.27*	.41**	–	–	–
7. Use of EF	−.16	−.10	.07	.26*	−.06	−.15	–	–
8. Number of EF reviews	−.01	.04	.23*	.34**	.19	.22	.16	–

Note. *p < .05, **p < .001. EF = Elaborated Feedback. Correlations for AutoLEC are to the right of and above the diagonal; correlations for TuinLECweb are to the left of and below the diagonal.

equivalent tests and observed an improvement in task-oriented reading skills. However, with this study, we have collected new evidence of its efficacy with an external reading comprehension test, which usually yields smaller effects than researcher-developed tests (Okkinga et al., 2018), and a bigger sample of sixth-graders. In this context, regarding the first research question (RQ1) about to what extent students improve their outcomes in textbase and situation model questions after the interventions, results show that both programs were effective, but reveal an opposite pattern in each condition. Thus, participants in TuinLECweb improved their scores in situation model but not in textbase questions, whereas in AutoLEC the opposite occurred. Moreover, training with TuinLECweb was effective for deep comprehension even when the time spent in the program was controlled. It is not striking that practicing question-answering with corrective feedback (KR y KCR) improves students' reading skills as long as the materials are appropriate (Llorens et al., 2015; National Reading Panel, 2000). However, strategy-based instruction is more effective for improving skills needed to answer questions that demand deep comprehension (i.e., situation model questions) than just practicing question-answering with feedback, even if this activity is carried out on a computer. Teaching and showing strategies for building a mental scheme of the text contents, examining the question demands, self-regulating the search process, and the search decision seems to especially benefit high level questions.

This result is in line with previous research on reading comprehension that highlights the relevance of strategy and explicit instruction for inferential questions. For example, Joseph et al. (2021) point out the necessity of explicit instruction for students with intellectual disabilities to adquiere complex reading skills. Similarly, Magliano et al. (2005) observed improvements only on inferential questions after reading strategy training. In addition, more than 30 years ago, Raphael and McKinney (1983) already found that strategy instruction on sources of information for answering questions improved scores on inferential questions, but just giving some guidance was enough for improving scores in explicit questions. This effect may be explained by the fact that TuinLECweb is designed to improve the skills required to answer questions that demand this level of comprehension, but also emphasises that explicit teaching and strategy instruction is more relevant for making inferences than for identifying explicit information (Ellman, 2017; Hall et al., 2020), also in task-oriented reading scenarios. Literal questions are easy to answer since the information required is in the text, however, inferential questions imply readers' knowledge. Therefore, whereas passive processes are usually enough for constructing a superficial representation of the text, building a situation model often demands reader-initiated processes, which are mainly strategic and require time and effort on the part of the reader (van den Broek & Helder, 2017).

In regard to the fact that students in TuinLECweb did not improve their scores in the textbase questions, it might be that, since they already exhibited good skills to locate information and have a good performance in the pretest, they had less room for improvement, as in Magliano's studies (2005).

To sum up, ITSs, like TuinLECweb, arise as promising tools to train task-oriented reading skills as they allow individualized strategy instruction and may support readers' efforts to deal with complex tasks. However, teachers need to be cautious, since using a computer to merely transpose texts and questions is not enough for training deep reading comprehension, and can even be detrimental if it is only used for presenting texts (Baron, 2021).

Regarding our second aim, we address students' behaviour in relation to the use of instructional components and resources of the programs (RQ2). In both interventions, neither minutes, nor using the aids or reviewing the feedback is related to reading learning gains. Regarding time spent in the program, although study-time usually relates to achievement, this relationship is far from linear (Godwin et al., 2021). It might be that the key is not time *per se*, but the students' skills and engagement and their mental activity during the time in the instruction (Naumann & Goldhammer, 2017). In our study, the minutes variable is a "black box" as it may provide similar information for different students' behaviours. For example, it does not discriminate between students who are more involved in the use of the program and those who have more trouble decoding. In other words, these results do not allow us to reach a single interpretation of the role of time.

With respect to the use of feedback and aids, the results indicate that students make limited use of these resources, which, in turn, do not relate to their learning gains. These findings reinforce some of the acknowledged results in the current literature regarding feedback processing and the seeking of help. Thus, Golke et al. (2015) suggest that when EF messages include KR and KCR feedback, students do not actively engage in processing the message, but focus their attention on the corrective components of the feedback. In addition, students usually struggle to identify when they need help, leading them not to seek help when they would need it (Aleven et al., 2003; Aleven & Koedinger, 2000). It is essential to keep these aspects in mind when developing computer-based interventions, especially if they are aimed at young learners who have not yet developed adequate self-regulation skills.

5. Conclusions and educational implications

Two main conclusions may arise from this study. First, the results confirm that just practicing question-answering with corrective feedback is an aid that fosters reading comprehension (National Reading Panel, 2000), but only for a surface level. AutoLEC represents this kind of training. In this case, autonomous practice with feedback has an impact.

However, in order to improve deep comprehension, just this former intervention is not enough. This would be the second conclusion. Explicit strategy instruction seems necessary for students to acquire the skills necessary to address high level questions in task-oriented reading situations (Afflerbach et al., 2020, pp. 98–118; Filderman et al., 2021). Obviously, receiving explicit instruction and guided practice requires more time than just practicing question-answering. However, this study confirms that receiving strategy instruction is effective to improve deep comprehension.

The results of this piece of research also point out the potentialities of computer-based instruction; however, participants' limited use of TuinLECweb instructional resources (i.e., use of aids and feedback review) also highlights the crucial role of students' self-regulation and metacognitive skills in order to benefit from an ITS. Therefore, students should be aware and willing to take advantage of strategy instruction and the aids provided when fostering reading comprehension. Hence, the first educational implication of this study is that explicit instruction of strategies should be a core element when designing an ITS. Thus, other ITSs aimed at teaching strategies in the field of reading comprehension yield similar results (Johnson-Glenberg, 2005, 2007; McNamara et al., 2006; Wijekumar et al., 2012, 2017).

A second educational implication is that it is important that instructors explain the role of the instructional phase and motivate students in order to benefit from the whole potential of TuinLECweb. In fact, TuinLECweb's promising results do not neglect the essential role of the teacher in the classroom. Personalised human instruction seems to obtain better results than computer tutoring (Jamshidifarsani et al., 2019; Xu et al., 2019), but TuinLECweb can be a way to complement it when the teacher is not available, working with a specific student or in distance learning caused by the pandemic situation. With respect to this, it is also worth mentioning that children at this age usually prefer to read on a screen, although their reading performance is better using paper (Baron, 2021), so teachers are also encouraged to use print texts, especially for long readings, and to complement this with a training in task-oriented reading with ITSs like TuiLECweb.

Third, another educational implication is that the materials selected were appropriate, providing an optimal challenge (since no floor or ceiling effects were found). Therefore, the results suggest that it is important for teachers when working on reading comprehension in their classrooms, with or without computers, to select an extensive volume and range of good texts that are representative of real-life reading situations and pose high-level questions (Ortega-Sánchez et al., 2019; Purcell-Gates et al., 2007; Rojas et al., 2019; Sepúlveda et al., 2020).

5.1. *Limitations and future research*

This piece of research has collected interesting results, but some cautions must be considered.

First, we have explored if some of the instructional components of TuinLECweb are related to posttest scores in comparison to AutoLEC, but in order to know exactly which one is more important for reading comprehension, an experimental study with several conditions contrasting the impact of each of the components should be carried out (Martin et al., 2007; Okkinga et al., 2018). Moreover, it would be interesting to collect online measures that allow us to ascertain students' cognitive and metacognitive processes as well as to explore how readers are using the instructional components and resources.

Second, the fact that we employed the same test for the pretest and the posttest to try to get a real measure of improvement, but which might raise the "learning effect". However, no feedback was administered to the students, so they did not know the correct answers. Moreover, Serrano et al. (2018) used three equivalent tests and observed an improvement compared to a pen and paper intervention. Although we have some reasons to consider that such an undesirable effect did not play a relevant role, still we consider that future studies might provide data to overcome doubts on this issue.

Third, although we have employed a bigger sample than in previous studies, we did not have enough participants to carry out a mixed model analysis to cast more light on the role of the reading instruction carried out by teachers in each school. Further studies should address this issue and explore how ITS results can be boosted by human instruction (ter Beek et al., 2018).

Although this study has some limitations, the enquiry performed here collects new evidence supporting the efficacy of evidence-based and theoretically grounded ITSs and raises interesting further research regarding how technology can be used to promote deep comprehension in task-oriented reading.

Credit author statement

Marian Serrano-Mendizábal: Conceptualization, Investigation, Data curation; Formal analysis, Writing – original draft; Funding acquisition; Software. Ruth Villalón: Conceptualization, Methodology, Investigation, Writing – original draft; Writing- Reviewing and Editing, Funding acquisition. Ángeles Melero: Methodology, Investigation, Writing- Reviewing and Editing. Belén Izquierdo-Magaldi: Methodology, Investigation, Resources, Writing- Reviewing and Editing.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.compedu.2023.104727.

References

Afflerbach, P., Hurt, M., & Cho, B. Y. (2020). Reading comprehension strategy instruction. In Daniel L. Dinsmore, Luke K. Fryer, & M. M. Parkinson (Eds.), *Handbook of strategies and strategic processing*. Routledge.

Aleven, V., & Koedinger, K. R. (2000). The need for tutorial dialog to support self-explanation. In C. P. Rose, & R. Freedman (Eds.), *Building dialogue systems for tutorial applications, papers of the 2000 AAAI Fall Symposium* (pp. 65–73). Menlo Park, CA: AAAI. Technical Report FS-00-01.

Aleven, V., Stahl, E., Schworm, S., Fischer, F., & Wallace, R. M. (2003). Help seeking and help design in interactive learning environments. *Review of Educational Research, 73*(2), 277–320.

American Psychological Association. (2016). Ethical principles of psychologist and code of Conduct. Retrieved from https://www.apa.org/ethics/code/ethics-code-2017.pdf .

Azevedo, R., & Bernard, R. M. (1995). A meta-analysis of the effects of feedback in computer-based instruction. *Journal of Educational Computing Research, 13*(2), 111–127. https://doi.org/10.2190/9LMD-3U28-3A0G-FTQT

Baron, N. S. (2021). *How we read now. Strategic Choices for Print, screen and audio*. Oxford University Press.

ter Beek, M., Brummer, L., Donker, A. S., & Opdenakker, M. C. J. (2018). Supporting secondary school students' reading comprehension in computer environments: A systematic review. *Journal of Computer Assisted Learning, 34*(5), 557–566. https://doi.org/10.1111/jcal.12260

Bernacki, M. L., Byrnes, J. P., & Cromley, J. G. (2012). The effects of achievement goals and self-regulated learning behaviors on reading comprehension in technology-enhanced learning environments. *Contemporary Educational Psychology, 37*(2), 148–161. https://doi.org/10.1016/j.cedpsych.2011.12.001

Britt, M. A., Rouet, J. F., & Durik, A. M. (2017). *Literacy beyond text comprehension: A theory of purposeful reading*. Routledge.

van den Broek, P., & Helder, A. (2017). Cognitive processes in discourse comprehension: Passive processes, reader-initiated processes, and evolving mental representations. *Discourse Processes, 54*(5–6), 360–372. https://doi.org/10.1080/0163853X.2017.1306677

Cataldo, M. G., & Oakhill, J. (2000). Why are poor comprehenders inefficient searchers? An investigation into the effects of text representation and spatial memory on the ability to locate information in text. *Journal of Educational Psychology, 92*(4), 791–799. https://psycnet.apa.org/doi/10.1037/0022-0663.92.4.791.

Cerdán, R., Gilabert, R., & Vidal-Abarca, E. (2011). Selecting information to answer questions: Strategic individual differences when searching texts. *Learning and Individual Differences, 21*(2), 201–205. https://psycnet.apa.org/doi/10.1016/j.lindif.2010.11.007.

van Dijk, T. A., & Kintsch, W. (1983). *Strategies of discourse comprehension*. Academic Press.

Duke, N. K., & Pearson, P. D. (2002). Effective practices for developing reading comprehension. In A. E. Forstup, & S. J. Samuels (Eds.), *What research has to say about reading instruction*. Newark, DE: International Reading Association. https://doi.org/10.1598/0872071774.10.

Ellman, A. M. (2017). Examining the impact of inference instruction on the literal and inferential comprehension of skilled and less skilled readers: A meta-analytic review. *Journal of Educational Psychology, 109*(6), ,761–781. https://doi.org/10.1037/edu0000180

Faul, F., Erdfelder, E., Lang, A. G., Buchner, A., & G* power 3. (2007). A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191. https://doi.org/10.3758/BF03193146

Filderman, M. J., Austin, C. R., Boucher, A. N., O'Donell, K., & Swanson, E. A. (2021). A meta-analysis of the effects of reading comprehension interventions on the reading comprehension outcomes of struggling readers in third through 12th grades. *Exceptional Children, 88*(2), 163–184.

Garcia-Pitxer, S. (2019). Els textos i les preguntes en els llibres de text d'educació secundària obligatòria i batxillerat. (Tesis Doctoral). Repositorio Institucional TESEO. https://www.educacion.gob.es/teseo/imprimirFicheroTesis.do?idFichero=jExsLGzVJgw%3D.

Gil, L., Martínez, T., & Vidal-Abarca, E. (2015). Online assessment of strategic reading literacy skills. *Computers & Education, 82*, 50–59. https://doi.org/10.1016/j.compedu.2014.10.026

Godwin, K. E., Seltman, H., Almeda, M., Davis Skerbetz, M., Kai, S., Baker, R. S., & Fisher, A. V. (2021). The elusive relationship between time on-task and learning: Not simply an issue of measurement. *Educational Psychology, 41*(4), 502–519. https://doi.org/10.1080/01443410.2021.1894324

Golan, D. D., Barzillai, M., & Katzir, T. (2018). The effect of presentation mode on children's reading preferences, performance, and self-evaluations. *Computers & Education, 126*, 346–358. https://doi.org/10.1016/j.compedu.2018.08.001

Goldman, S. R., Lawless, K. A., Gomez, K. W., Braasch, J. L. G., McLeod, S., & Manning, F. (2010). Literacy in the digital world: Comprehending and learning from multiple sources. In M. G. McKeown, & L. Kucan (Eds.), *Bringing reading research to life* (pp. 257–284). New York: Guilford.

Golke, S., Dörfler, T., & Cordula, A. (2015). The impact of elaborated feedback on text comprehension within a computer-based assessment. *Learning and Instruction, 39*, 123–136. https://doi.org/10.1016/j.learninstruc.2015.05.009

Graesser, A. C., D'Mello, S., & Person, N. (2009). Meta-knowledge in tutoring. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Handbook of metacognition in education* (pp. 361–382). Taylor & Francis Group: Routledge.

Guthrie, J. T., & Kirsch, I. S. (1987). Distinctions between reading comprehension and locating information in text. *Journal of Educational Psychology, 79*(3), 220–227. https://doi.org/10.1037/0022-0663.79.3.220

Hall, C., Vaughn, S., Barnes, M. A., Stewart, A. A., Austin, C. R., & Roberts, G. (2020). The effects of inference instruction on the reading comprehension of English learners with reading comprehension difficulties. *Remedial and Special Education, 41*(5), 259–270.

Jamshidifarsani, H., Garbaya, S., Lim, T., Blazevic, P., & Ritchie, J. M. (2019). Technology-based reading intervention programs for elementary grades: An analytical review. *Computers & Education, 128*, 427–451. https://doi.org/10.1016/j.compedu.2018.10.003

Johnson-Glenberg, M. C. (2005). Web-based training of metacognitive strategies for text comprehension: Focus on poor comprehenders. *Reading and Writing, 18*(7), 755–786. https://psycnet.apa.org/doi/10.1007/s11145-005-0956-5.

Johnson-Glenberg, M. C. (2007). Web-based reading comprehension instruction: Three studies of 3D-readers. Reading comprehension strategies: Theories, interventions, and technologies. In Danielle S. McNamara (Ed.), *Reading comprehesion strategies: Theories, interventions, and technologies* (pp. 293–324). Lawrence Erlbaum.

Joseph, L., Ross, K., Xia, Q., Amspaugh, L. A., & Accurso, J. (2021). Reading comprehension instruction for students with intellectual disabilities: A systematic literature review. *International Journal of Disability, Development and Education*. https://doi.org/10.1080/1034912x.2021.1892033. Advance online publication.

van der Kleij, F. M., Feskens, R. C. W., & Eggen, T. J. H. M. (2015). Effects of feedback in a computer-based learning environment on students' learning outcomes: A meta-analysis. *Review of Educational Research, 85*(4), 475–511. https://doi.org/10.3102/0034654314564881

Kobasigawa, A., Lacasse, M. A., & MacDonald, V. A. (1988). Use of headings by children for text search. *Canadian Journal of Behavioral Science, 20*, 50–63. https://doi.org/10.1037/h0079915

Lan, Y. C., Lo, Y. L., & Hsu, Y. S. (2014). The effects of meta-cognitive instruction on students' reading comprehension in computerized reading contexts: A quantitative meta-analysis. *Journal of Educational Technology & Society, 17*(4), 186–202.

León, J. A., Escudero, I., & Olmos, R. (2012). *Evaluación de la comprensión lectora (ECOMPLEC)*. TEA Ediciones.

Llorens, A. C., Cerdán, R., & Vidal-Abarca, E. (2014). Adaptive formative feedback to improve strategic search decisions in task-oriented reading. *Journal of Computer Assisted Learning, 30*(3), 233–251. https://doi.org/10.1111/jcal.12050

Llorens, A. C., Gil, L., Vidal-Abarca, E., Martínez, T., Mañá, A., & Gilabert, R. (2011). Prueba de Competencia Lectora para Educación Secundaria (CompLEC). *Psicothema, 23*(4), 808–817.

Llorens, A. C., Vidal-Abarca, E., & Cerdán, R. (2016). Formative feedback to transfer self-regulation of task-oriented reading strategies. *Journal of Computer Assisted Learning, 32*(4), 314–331. https://psycnet.apa.org/doi/10.1111/jcal.12134.

Llorens, A. C., Vidal-Abarca, E., Cerdán, R., & Ávila, V. (2015). Does formative feedback on search behaviour help students in answering comprehension questions from an available text?/¿ Ayuda la retroalimentación formativa sobre el comportamiento de búsqueda a contestar preguntas de comprensión en lecturas con texto disponible? *Infancia Y Aprendizaje, 38*(4), 808–841. https://doi.org/10.1080/02103702.2015.1076269

Lust, G., Elen, J., & Clarebout, G. (2013). Regulation of tool-use within a blended course: Student differences and performance effects. *Computers & Education, 60,*(1), 385–395. https://doi.org/10.1016/j.compedu.2012.09.001

Magliano, J. P., Todaro, S., Millis, K., Wiemer-Hastings, K., Kim, H. J., & McNamara, D. S. (2005). Changes in reading strategies as a function of reading training: A comparison of live and computerized training. *Journal of Educational Computing Research, 32*(2), 185–208. https://doi.org/10.2190/1LN8-7BQE-8TN0-M91L

Martínez, T., Vidal-Abarca, E., Gil, L., & Gilabert, R. (2009). On-line assessment of comprehension processes. *Spanish Journal of Psychology, 12*(1), 308–319. https://doi.org/10.1017/S1138741600001700

Martin, F., Klein, J. D., & Sullivan, H. (2007). The impact of instructional elements in computer-based instruction. *British Journal of Educational Technology, 38*(4), 623–636. https://doi.org/10.1111/j.1467-8535.2006.00670.x

McNamara, D. S. (2010). Strategies to read and learn: Overcoming learning by consumption. *Medical Education, 44*(4), 340–346. https://doi.org/10.1111/j.1365-2923.2009.03550.x

McNamara, D. S. (2021). If integration is the keystone of comprehension: Inferencing is the key. *Discourse Processes: A Multidisciplinary Journal, 58*(1), 86–91. https://doi.org/10.1080/0163853X.2020.1788323

McNamara, D. S., O'Reilly, T. P., Best, R. M., & Ozuru, Y. (2006). Improving adolescent students' reading comprehension with iSTART. *Journal of Educational Computing Research, 34*(2), 147–171.

Milheim, W. D., & Martin, B. L. (1991). Theoretical bases for the use of learner control: Three different perspectives. *Journal of Computer-Based Instruction, 18*(3), 99–105.

Morgan, B. A., Hogan, A. M., Hampton, A. J., Lippert, A. M., & Graesser, A. C. (2020). The need for personalized learning and the potential of intelligent tutoring systems. In P. van Meter, A. List, D. Lombardin, & P. Kendeou (Eds.), *Handbook of learning from multiple representations and perspectives* (pp. 495–512). New York: Routledge.

Mullis, I. V. S., & Martin, M. O. (2019). PIRLS 2021 assessment frameworks. TIMSS & PIRLS international study center. In *Boston college and international association for the evaluation of educational achievement (IEA)*. Lynch School of Education. Retrieved from https://timssandpirls.bc.edu/pirls2021/frameworks/.

Murphy, P. (2010). Web-based collaborative reading exercises for learners in remote locations: The effects of computer-mediated feedback and interaction via computermediated communication. *ReCALL, 22*, 112–134. https://doi.org/10.1017/S0958344010000030

National Reading Panel. (2000). Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implication for reading instruction: Reports of the subgroups. *National Institute of Child Health and Human Development*.

Naumann, J., & Goldhammer, F. (2017). Time-on-task effects in digital reading are non-linear and moderated by persons' skills and tasks' demands. *Learning and Individual Differences, 53*, 1–16. https://doi.org/10.1016/j.lindif.2016.10.002

Ness, M. (2011). Explicit reading comprehension instruction in elementary classrooms:teacher use of reading comprehension strategies. *Journal of Research in Childhood Education, 25*(1), 98–117. https://doi.org/10.1080/02568543.2010.531076

OECD. (2018). *Teaching for the future: Effective classroom practices to transform education*. OECD Publishing. https://doi.org/10.1787/9789264293243-en

Okkinga, M., van Steensel, R., van Gelderen, A. J. S., van Schhoten, E., Sleegers, P. J. C., & Arends, L. R. (2018). Effectiveness of reading-strategy interventions in whole-classrooms: A meta analyses. *Educational Psychology Review, 30*, 1215–1239. https://doi.org/10.1007/s10648-018-9445-7

Orellana, P., Melo, C., Baldwin, P., de Julio, S., & Pezoa, J. (2020). The relationship between motivation to read and reading comprehension in chilean elementary students. *Reading and Writing, 33*, 2437–2458. https://doi.org/10.1007/s11145-020-10051-3

Ortega-Sánchez, D., Sanz de la Cal, E., & Ibáñez, J. (2019). Literacies and the development of social, critical, and creative thought in textbook activities for primary education in social sciences and the Spanish language. *Frontiers in Psychology, 10*. https://doi.org/10.3389/fpsyg.2019.025720, 2572.

Pearson, P. D., & Dole, J. A. (1987). Explicit comprehension instruction: A review of research and a new conceptualization of instruction. *The Elementary School Journal, 88*(2), 151–165. https://doi.org/10.1086/461530

Ponce, H. R., López, M. J., & Mayer, R. E. (2012). Instructional effectiveness of a computer-supported program for teaching reading comprehension strategies. *Computers & Education, 59*, 1170–1183. https://doi.org/10.1016/j.compedu.2012.05.013

Purcell-Gates, V., Duke, N. K., & Martineau, J. A. (2007). Learning to read and write genre- specific text: Roles of authentic experience and explicit teaching. *Reading Research Quarterly, 42*(1), 8–45. https://doi.org/10.1598/RRQ.42.1.1

Raphael, T., Au, K. H., & QAR. (2005). Enhancing comprehension and test taking across grades and content areas. *The Reading Teacher, 59*(3), 206–221. https://do.orgi/10.1598/RT.59.3.1.

Raphael, T., & McKinney, J. (1983). An examination of fifth- and eighth-grade children's question-answering behavior: An instructional study in metacognition. *Journal of Reading Behavior, 15*, 67–86.

Rojas, S. P., Meneses, A., & Sánchez, E. (2019). Teachers' scaffolding science reading comprehension in low-income schools: How to improve achievement in science. *International Journal of Science Education, 41*(13), 1827–1847. https://doi.org/10.1080/09500693.2019.1641855

Rosenshine, B., & Meister, C. (1994). Reciprocal teaching: A review of the research. *Review of Educational Research, 64*, 479–530. https://doi.org/10.3102/00346543064004479

Rouet, J.-F. (2006). *The skills of document use: From text comprehension to web-based learning*. Lawrence Erlbaum.

Rouet, J.-F., & Coutelet, B. (2008). The acquisition of document search strategies in grade school students. *Applied Cognitive Psychology, 22*(3), 389–406. https://doi.org/10.1002/acp.1415

Saint, J., Fan, Y., Gašević, D., & Pardo, A. (2022). Temporally-focused analytics of self-regulated learning: A systematic review of literatura. Computers and education: *Artificial Intelligence, 3*, Article 100060. https://doi.org/10.1016/j.caeai.2022.100060

Sepúlveda, A., Minte, A., & Díaz-Levicoy, D. (2020). Characterization of questions in textbooks of natural science in Chilean primary education. *Educação e Pesquisa, 46*(6). https://doi.org/10.1590/S1678-4634202046224118

Serrano, M. A., Vidal-Abarca, E., & Ferrer, A. (2018). Teaching self-regulation strategies via an intelligent tutoring system (TuinLECweb): Effects for low-skilled comprehenders. *Journal of Computer Assisted Learning, 34*(5), 515–525. https://doi.org/10.1111/jcal.12256

Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research, 78*(1), 153–189.

Smith, R., Snow, P., Serry, T., & Hammond, L. (2021). The role of background knowledge in reading comprehension: A critical review. *Reading Psychology, 42*(3), 214–240. https://www.tandfonline.com/doi/abs/10.1080/02702711.2021.1888348.

Snow, C. (2002). Reading for understanding: Toward an R&D program in reading comprehension. *RAND Reading Study Group*.

Snow, E. L., Allen, L. K., Jacovina, M. E., & McNamara, D. S. (2015). Does agency matter?: Exploring the impact of controlled behaviors within a game-based environment. *Computers & Education, 82*, 378–392. https://doi.org/10.1016/j.compedu.2014.12.011

Snow, E., Jackson, G. T., & McNamara, D. S. (2014). Emergent behaviors in computer-based learning environments: Computational signals of catching up. *Computers in Human Behavior, 41*, 62–70. https://doi.org/10.1016/j.chb.2014.09.011

Sun, Y., Wang, J., Dong, Y., Zheng, H., Yang, J., Zhao, Y., & Dong, W. (2021). The relationship between reading strategy and reading comprehension: A meta-analysis. *Frontiers in Psychology, 12*, Article 635289. https://doi.org/10.3389/fpsyg.2021.635289

Swart, E. K., Nielen, T. M., & de Jong, M. T. S. (2019). Supporting learning from text: A meta-analysis on the timing and content of effective feedback. *Educational Research Review, 28*(100296). https://doi.org/10.1016/j.edurev.2019.100296

Symons, S., MacLatchy-Gaudet, H., Stone, T. D., & Reynolds, P. L. (2001). Strategy instruction for elementary students searching informational text. *Scientific Studies of Reading, 5*(1), 1–33. https://doi.org/10.1207/S1532799XSSR0501_1

Tawfik, A. A., Graesser, A., Gatewood, J., & Gishbaugher, J. (2020). Role of questions in inquiry-based instruction: Towards a design taxonomy for question-asking and implications for design. *Educational Technology Research & Development, 68*, 653–678. https://doi.org/10.1007/s11423-020-09738-9

Vidal-Abarca, E., Gilabert, R., Ferrer, A., Ávila, V., Martínez, T., Mañá, A., Llorens, A. C., Gil, L., Cerdán, R., Ramos, L., & Serrano, M. A. (2014). TuinLEC an intelligent tutoring system to improve reading literacy skills/TuninLEC, un tutor inteligente para mejorar la comprensión lectora. *Infancia Y Aprendizaje, 37*(1), 25–56. https://doi.org/10.1080/02103702.2014.881657

Vidal-Abarca, E., Mañá, A., & Gil, L. (2010). Individual differences for self-regulating task-oriented reading activities. *Journal of Educational Psychology, 102*(4), 817–826. https://doi.org/10.1037/a0020062

Vidal-Abarca, E., Martinez, T., Salmerón, L., Cerdán, R., Gilabert, R., Gil, L., Mañá, A., Llorens, A. C., & Ferris, R. (2011). Recording online processes in task-oriented reading with read & answer. *Behavior Research Methods, 43*(1), 179–192. https://doi.org/10.3758/s13428-010-0032-1

Vidal-Abarca, E., Serrano, M. A., Ramos, L., Gil, L., & Ferrer, A. (2017). An intelligent tutoring system to teach task-oriented reading skills to young adolescents. In C. McNamara (Ed.), *Adaptive educational technologies for literacy instruction*. Taylor & Francis: Routledge.

Vogel, J. J., Vogel, D. S., Cannon-Bowers, J., Bowers, C. A., Muse, K., & Wright, M. (2006). Computer gaming and interactive simulations for learning: A meta-analysis. *Journal of Educational Computing Research, 34*, 229–243. https://doi.org/10.2190/FLHV-K4WA-WPVQ-H0YM

White, S., Chen, J., & Forsyth, B. (2010). Reading-related literacy activities of American adults: Time spent, task types, and cognitive skills used. *Journal of Literacy Research, 42*(3), 276–307.

Wigfield, A., Gladstone, J. R., & Turci, L. (2016). Beyond cognition: Reading motivation and reading comprehension. *Child development perspectives, 10*(3), 190–195. https://doi.org/10.1111/cdep.12184

Wijekumar, K. K., Meyer, B. J., & Lei, P. (2012). Large-scale randomized controlled trial with 4th graders using intelligent tutoring of the structure strategy to improve nonfiction reading comprehension. *Educational Technology Research & Development, 60*(6), 987–1013. https://doi.org/10.1037/edu0000168

Wijekumar, K. K., Meyer, B. J., & Lei, P. (2017). Web-based text structure strategy instruction improves seventh graders' content area reading comprehension. *Journal of Educational Psychology, 109*(6), 741. https://doi.org/10.1037/edu0000168

Wijekumar, K., Zhang, S., Joshi, R. M., & Peti-Stantic, A. (2021). Introduction to the special issue: Textbook content and organization-why it matters to reading comprehension in elementary grades? *Technology, Knowledge and Learning, 26*(2), 243–249. https://doi.org/10.1007/s10758-021-09505-6

Xu, Z., Wijekumar, K., Ramirez, G., Hu, X., & Irey, R. (2019). The effectiveness of intelligent tutoring systems on K-12 students' reading comprehension: A meta-analysis. *British Journal of Educational Technology, 50*(6), 3119–3137. https://doi.org/10.1111/bjet.12758