



Instructional effectiveness of a computer-supported program for teaching reading comprehension strategies

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ABSTRACT

This article examines the effectiveness of a computer-based instructional program (e-PELS) aimed at direct instruction in a collection of reading comprehension strategies. In e-PELS, students learn to highlight and outline expository passages based on various types of text structures (such as comparison or cause-and-effect) as well as to paraphrase, self-question, and summarize. The study involved 1041 fourth-grade elementary students from 21 schools distributed in three regions in central Chile. Participant teachers integrated this program into the Spanish language curriculum, instructing their students during thirty sessions of 90 min each during one school semester. Pretest-to-posttest gains in reading comprehension scores were significantly greater for students instructed with this program than for students who received traditional instruction ($d = .5$), with particularly strong effects for lower-achieving students ($d = .7$). The findings support the efficacy of direct instruction in specific learning strategies in a computer-based environment.

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1. Introduction

This study evaluated the effectiveness of a computer-supported program for teaching reading comprehension strategies. The program included visual cognitive strategies such as highlighting key ideas and using graphic organizers to organize information based on types of text structures, and verbal strategies such as paraphrasing, self-questioning and summarizing. Does direct instruction using a multiple-strategy program embedded in a software application improve reading comprehension? This was the main research question that guided this study. The strategies embedded in the software application were specially developed and selected to meet the curricular standards and requirements of 4th grade elementary students.

2. Strategy-based comprehension instruction

A learning strategy is defined as the set of actions carried out by a learner during learning which are intended to improve knowledge acquisition (Dole, Nokes, & Driets, 2009). Cognitive strategies for reading comprehension support readers' efforts to select, organize, interpret and understand text (Vellutino, 2003). Reading comprehension strategies can be grouped into levels according to the cognitive processes they support. One scheme, proposed by Román and Gallego (1994), includes strategies for information acquisition (e.g., text underlining, text coloring, or reading aloud); for information coding (e.g., self-questioning, paraphrasing, sequencing, diagrams, conceptual maps, or graphic organizers); for information retrieval (e.g., mental imaging, abstracting, or problem solving); and for information processing support (e.g., making schedules or forming study groups). In the SOI model, Mayer (2008) suggests that learning strategies can be classified in terms of three different cognitive processes: select — paying attention to relevant information; organize — building a coherent structure; and integrate — connecting incoming information with existing relevant knowledge activated from long-term memory.

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Reviews of research on cognitive strategy instruction indicate that there is sufficient research evidence to encourage the idea that cognitive and metacognitive strategies can improve reading comprehension and that they can be taught effectively (Mayer, 2008; Pressley & Woloshyn, 1995; Vellutino, 2003). A research study by the RAND Reading Study Group (RAND, 2002) in the United States summarized a series of findings on what works for comprehension instruction. The following findings were particularly relevant for the present study: (1) Enhancing reading fluency has a significant effect on word recognition but moderate effect on reading comprehension. (2) Instruction on specific learning strategies and monitoring mechanisms has proved effective in fostering reading comprehension. (3) Low-achieving students benefit particularly from explicit teaching of comprehension strategies. (4) Curricular integration of comprehension strategies into specific content domains, such as history and science, further develop reading comprehension. (5) Finally, teachers should dedicate more time and offer more support to students in the classroom, particularly in primary and upper elementary grades, to teach specific reading comprehension strategies.

Focusing specifically on reading comprehension instruction and its relation with learning strategies, Raphael, George, Weber, and Nies (2009) reviewed research since 1980s, separating research on instructional approaches in three main stages: (1) individual strategy research, (2) frameworks for multiple strategies, and (3) coherence in comprehension instruction. The first stage had its origins in research carried out during the 1980s and early 1990s. This brought together cognitive psychologists, educators, linguistics and others interested in cognitive mechanisms to improve reading comprehension. The second stage had its origins in research on individual strategies, but investigating sophisticated models that integrate multiple comprehension strategies. The third and current stage, according to these authors, has focused on research whose object of study has moved beyond the individual classroom, integrating networks of teachers within schools or groups of schools. It examines coherence in literacy curriculum, studying factors, and conditions and processes that make a literacy program successful.

Research on teaching individual strategies has focused mainly on identifying those strategies that proficient readers use, on how to teach and evaluate those strategies, and their impact on reading comprehension (Raphael et al., 2009). A research survey by the National Reading Panel (2000) in the United States identified the following single strategies that seem to be effective and show potential as teaching methods: metacognitive mechanisms for comprehension, collaborative learning, graphic organizers, questioning, and summarizing. On the other hand, research on multiple-strategy instruction has built on research on individual strategies but also considers that learning takes place in complex settings, and that knowledge is socially constructed, dialogical and interactive in nature (Raphael et al., 2009). Consequently, the approaches or frameworks developed during this stage sought to integrate different individual strategies to improve reading comprehension in classroom activity settings. Some well-known and researched multiple-strategy approaches are Reciprocal Teaching (Palincsar & Brown, 1984), Concept-oriented Reading Instruction (Guthrie et al., 2004), Survey, Question, Read, Recite and Review (McDaniel, Howard, & Einstein, 2009) and collaborative reasoning (Clark et al., 2003).

In general, empirical evidence demonstrates that multiple-strategy instruction integrated into the curriculum can work well in schools and can improve reading comprehension over students instructed with traditional methods (RAND, 2002). For example, in a review of 16 studies on reciprocal teaching, Rosenshine and Meister (1994) concluded that this approach enhances reading comprehension, with significant score gains by students trained with reciprocal teaching. In the case of collaborative reasoning, Reznitskaya et al. (2009) studied the effects of this approach on the distribution of participation, student argumentation quality, use of rhetorical moves and their impact on argument construction, and variety of questions used by students; they found improvement in argumentative and communication skills. Finally, regarding concept-oriented reading instruction, in several quasi-experimental studies; the conclusion was that the experimental groups in comparison with the control groups achieved a significant gain in reading comprehension (Guthrie et al., 2004; Guthrie et al., 2009).

3. E-PELS: a multiple-strategy instruction program for reading comprehension

An important new issue addressed in this study concerns whether cognitive strategies for reading comprehension can be taught effectively within a computer-based system that systematically uses direct instruction and practice. The computer-supported multiple-strategy program was named e-PELS ("Programa de Entrenamiento en Lectura Significativa" or "Program in Deep Reading Comprehension"). The basic idea to develop e-PELS was taken from Román (2004) who designed a paper-based instruction program in reading comprehension built upon a set of information processing learning strategies that included underlining, paraphrasing, self-questioning, text structure and conceptual maps. Based on this idea, we developed a software application that embedded similar strategies, but replaced conceptual mapping by the use of interactive graphic organizers; additionally, we included summarizing and conceptualizing strategies. This new application took advantage of our previous work on the development of interactive graphic organizers. A first version of e-PELS was developed with a more primitive interface than the one used in this study and tested with a small group of fourth-grade students.

The following three figures show e-PELS in use. The instructional activities encouraged teachers and their students to work on each strategy sequentially and systematically with different short texts. In general, they started by reading the text on the computer screen or projected on the whiteboard when a data projector was in use. Thirty short texts were provided with e-PELS, but teachers were free to incorporate new ones. If some words were not understood, teachers used the word-box functionality to define the respective word in a dialogical process, asking students to derive its classification (e.g., verb or adjective), its synonyms, examples and the best definition found in a dictionary. Following this process, students were asked to highlight key ideas and use them to paraphrase the original text, as illustrated in Fig. 1. Next, students worked on identifying the type of text at hand (i.e., narrative, informative, news and poems) by choosing and completing the visual schemes provided (see Fig. 2). After they have finished with this strategy, students were asked by their teachers to choose one or two graphic organizers to identify the main arguments in the text, by using cause-and-effect relationship, comparison-and-contrast, sequence or pro-and-con structures (see Fig. 3). Naturally, this process took more than one class, and this is the main reason to have allocated thirty 90-min sessions to work on all strategies during one school semester, as indicated in Table 2.

Fig. 2 shows the text structure strategy being used; in this case, the structure corresponds to an informative text. E-PELS provides four different text structures that can be used according to the type of text being analyzed in a learning activity.

Fig. 3 shows a differences and similarities interactive graphic organizer that has been completed for the organization of ideas and arguments from a written text. In the large vertical rectangles, the two elements under comparison must be written (e.g., butterflies and

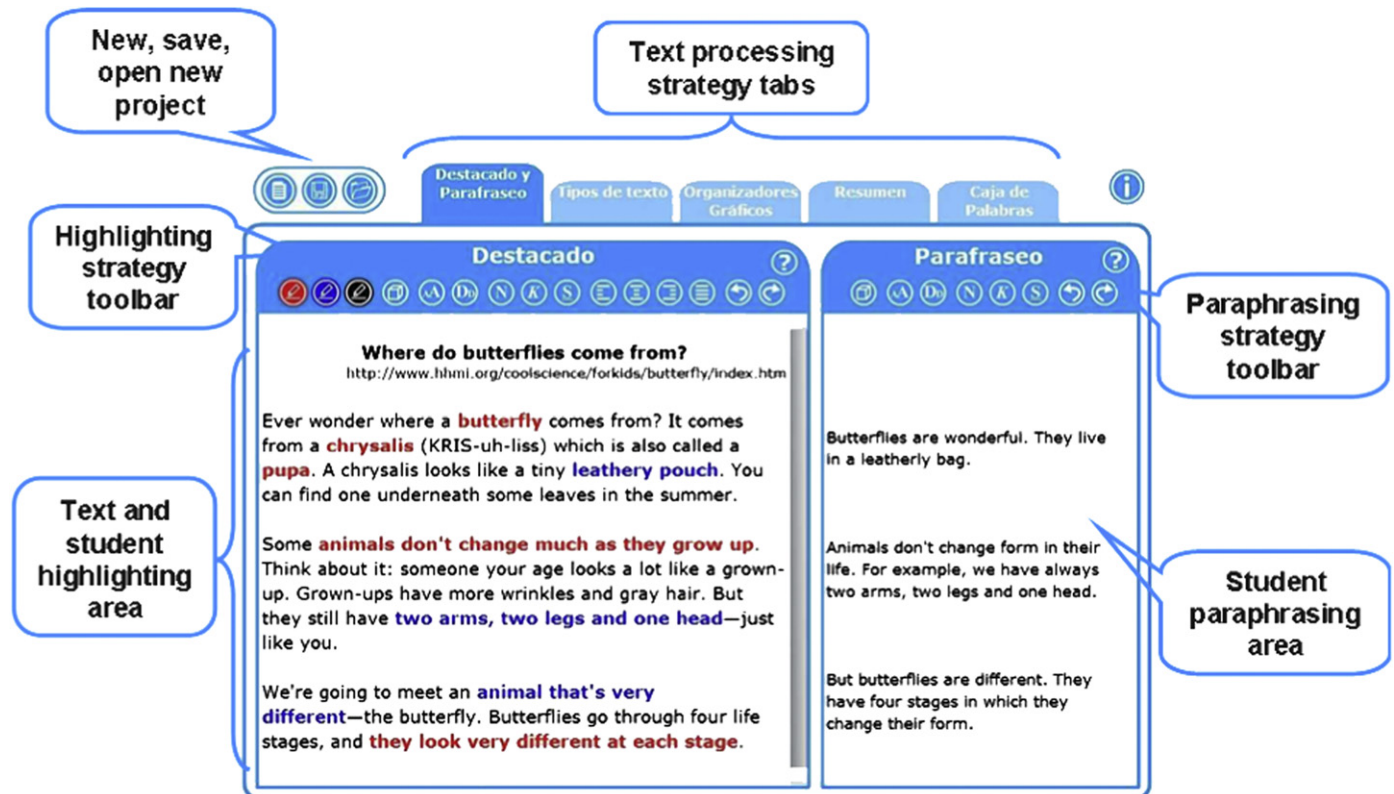


Fig. 1. A general overview of e-PELS.

people). In the inner rectangles, the identified similarities are included (e.g., both are living beings and grow up in stages). In the outer rectangles, the recognized differences are pointed out (e.g., butterflies are insects, change their form, have four life styles and look different in each stage, whereas people are human beings, keep the same form from childhood to old age, and look similar in each stage).

Teachers were trained on how each strategy worked and how it was implemented within e-PELS. They were also supported during the implementation in the classroom through specific instruction on the more demanding strategies, such as text structures and graphic organizers.

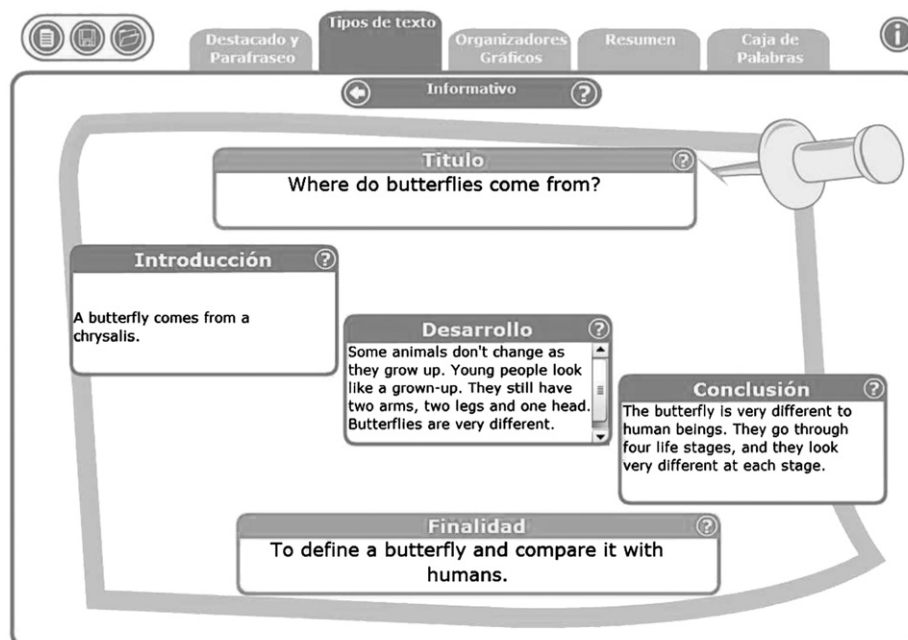


Fig. 2. One of the text structure.

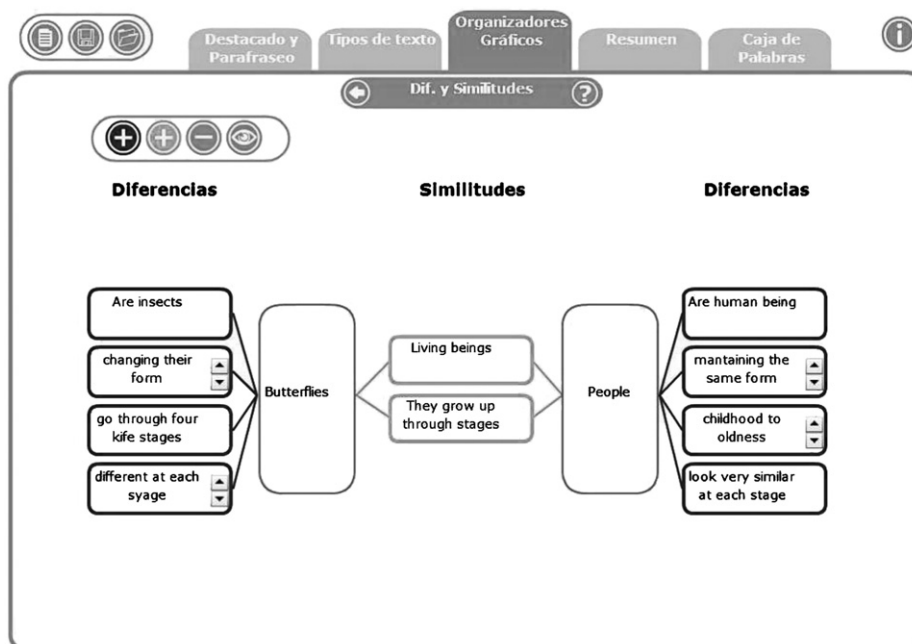


Fig. 3. One of the interactive graphic organizers.

4. Research questions

The theoretical motivation for this study comes from the idea that expertise in reading involves learning how and when to use a collection of cognitive strategies (Mayer, 2008; Pressley & Woloshyn, 1995). In particular, reading comprehension depends of the reader's knowledge of cognitive strategies for recognizing types of text structures and translating them into spatial arrangements (Chambliss & Calfee, 1998; Cook & Mayer, 1988; Holley, Dansereau, McDonald, Garland, & Collins, 1979; Jairam & Kiewra, 2010). Practice with translating text into other forms of representation such as graphic organizers represents a form of deliberate practice — sustained practice on an authentic task at a challenging level (Ericsson, Charness, Feltovich, & Hoffman, 2006). The e-PELS program is intended to accomplish this goal and therefore is predicted to improve students' reading comprehension more effectively than conventional instruction, particularly for lower-achieving students who are less likely to develop effective cognitive strategies on their own.

The following research questions guided this study and the respective data analysis and main conclusions: (1) Do students improve their reading comprehension skill more with e-PELS than with traditional instruction? (2) Is the e-PELS treatment effective for low-achieving students and high-achieving students? (3) Is the e-PELS treatment effective for boys and girls?

5. Method

5.1. Participants

This study involved 1041 fourth-grade elementary students from 21 schools distributed in three regions in central Chile. A total of 939 students from 18 schools constituted the e-PELS (experimental) group and 102 students from 3 schools constituted the traditional instruction (control) group. Several schools participated with more than one class, yielding 27 classes in the e-PELS group and 3 classes in the traditional instruction (TI) group. Table 1 shows schools distributed by region, number of participants in each class, its administration, local area, socioeconomic group, and reading achievement test scores (based on SIMCE) and level of achievement based on these scores. SIMCE ("Sistema de Medición de la Calidad de la Educación" or System to Measure Quality of Education) is a compulsory test taken by all Chilean students that measures achievement in reading, math, and science which is used by the national government to assess the overall proficiency level of schools and to implement related educational policies.

The SIMCE scores shown in Table 1 correspond to the results obtained by each school one year before the study took place, and are intended to assess the overall school rather than individual students. The SIMCE scores obtained by each school are relatively stable over time so they offer relevant information regarding their educational performance. In general, there is a high correlation between students' socioeconomic background and schools' performance in this test. SIMCE reading achievement levels for 4th grade are categorized in three groups: initial, intermediate and advanced. (1) Initial level includes students who are learning to read short sentences to those students whose reading comprehension fluctuates. (2) Students in the intermediate level demonstrate reading comprehension skills such as ability to extract easy-to-find explicit information, make inferences from repeated or highlighted text, interpret familiar expressions, identify the type of text included in the curriculum, recognize some aspects of the communicative situation, understand what a familiar text is about, and express opinions in relation to facts or acts of text characters. (3) Students in the advanced level are able to comprehend unfamiliar texts, integrate different types of information, recognize causal relationships, understand unfamiliar expressions in figurative language, and infer the meaning of unfamiliar words. Table 1 also includes data regarding school locales (mainly from urban areas, 77.8%) and socioeconomic background (largely from middle class background, 88.9%). In addition, municipalities administrated 52.4% of the schools, and 48.6%

Table 1
Characteristics of participant schools.

Region	Administration	Area	Socioeconomic group	School	SIMCE 2008		Class	N
					Score	Level		
V	Municipal	Rural	Middle	School One	268	Intermediate	A	41
							B	43
	Private	Urban	Middle-Low Middle	School Two	233	Initial	A	34
							A	35
				School Three	244	Intermediate	B	37
							C	34
				School Four	277	Intermediate	A	35
				School Five	257	Intermediate	A	41
				School Six	242	Intermediate	A	16
				School Seven	268	Intermediate	A	25
VI	Municipal	Rural	Low Middle-Low	School Eight	235	Initial	A	15
				School Nine	215	Initial	A	18
				School Ten	209	Initial	A	17
				School Eleven*	278	Intermediate	A	25
		Urban	Low Middle-Low Middle	School Twelve	242	Intermediate	A	25
							B	23
				School Thirteen	251	Intermediate	A	36
				School Fourteen*	256	Intermediate	A	45
				School Fifteen	289	Advanced	A	41
				School Sixteen	307	Advanced	B	41
XIII	Municipal	Urban	Middle-Low Middle Middle-Upper				A	39
							A	46
							B	44
				School Eighteen*	286	Advanced	A	32
				School Nineteen	295	Advanced	A	42
							B	43
				School Twenty	285	Advanced	A	40
							B	42
				School Twenty-One	287	Advanced	A	44
							B	42

Note. Asterisk (*) indicates schools in the traditional instruction group.

belonged to private owners. Both municipalities and private owners receive subsidies by the state known as vouchers, based on the number of students enrolled.

5.2. Variables and measures

The independent variable was instructional method for reading comprehension, in which students in the experimental group used e-PELS over the course of a semester within a classroom setting and students in the control group learned under traditional instruction. Of all the participating schools, three were selected to be in the traditional instruction group.

The dependent measure was reading comprehension performance, as measured by a standardized test sanctioned for use in Chile's schools called the Comprehension Test of Progressive Linguistic Complexity (or, in Spanish, "Prueba de Comprensión Lectora de Complejidad Lingüística Progresiva," abbreviated as CLP) (Alliende, Condemarín, & Milicic, 2004). The CLP was the only standardized and validated test available for Chilean elementary level students at the time this study. The CLP considers the complexity level of texts and the characteristics of reader groups for whom those texts are addressed. It defines eight levels of complexity that takes into consideration psychographic characteristics of readers (age, level of schooling and learning of readers, among others). Each level implies increasing reading comprehension difficulties given by a series of texts used in each level. In this study, CLP level 3 form A was used as the pretest and form B as the posttest. CLP level 3 involves the domain of three specific abilities: (a) to capture the overall meaning of a sentence by indicating another sentence of similar meaning; (b) to follow written instructions that indicate different ways of working with a text; and (c) to read descriptions and simple narrations, and demonstrate that statements contained in such texts are understood. According to Alliende et al. (2004), the latter ability entails comprehension of a variety of characters and situations, implying the ability to understand not only simple single sentences but also the overall meaning of the text.

Both CLP forms are constituted by four subtests. In form A of the CLP, the four subtests contain 7, 6, 5 and 3 questions respectively, whereas in form B there are 7, 7, 4, and 3 questions. The first and second subtests in both forms verify the first ability indicated above, that is, if the learner is able to specify the meaning of a set of phrases by indicating other modes of expressing the same. The third subtest in each form put the learner in contact with a text that represents a variety of characters and situations with simplicity and using familiar terms. Questions in this subset check if the learner understands some facts that are not said explicitly with one phrase but corresponds to the general meaning of what is said. Finally, the fourth subtest checks that comprehension of a group of six related expressions, more complex and abstract than those included in the previous subtests. This helps to check if learners are able to understand the meaning of a difficult expression with the support of an explanation (Alliende et al., 2004).

In the validation process of CLP test undertook by Alliende et al. (2004), the norming group obtained an average score of 15.46 in form A and 15.21 in form B with a sample size of 123 students. Based on the consistency of these results and the small difference between both tests, we decided to use the parallel forms A and form B as pretest and posttest assessments in our quasi-experimental evaluation respectively. This is an important observation to take into consideration since in order to avoid students remembering the questions from the pretest, the availability of a parallel form of the same test was considered an advantage.

In addition to measuring reading comprehension, the research team administered a learning strategy test to assess how well students were performing with each strategy embedded in e-PELS. This test was composed by two main activities. The first activity asked students, first, to read a short text; second, to highlight main ideas; and third, to use the highlighted ideas to paraphrase a new text. The second activity asked students, first, to read one-page text; second, to complete a narrative text structures; third, to fill in the sequence graphic organizer; and fourth, to complete the word-box by defining the word “fairy” (in Spanish “hada”) that was part of the text.

5.3. Teacher instruction

A 60-h comprehensive course was offered from September to December 2008 to participant teachers before the application of e-PELS in the classroom (March–July 2009). This course ran for three months with classes divided by region and plenary sessions once a month that took place in Santiago. Plenary sessions were essential for teachers and researchers since it allowed sharing vital information about similar concerns regarding the use of e-PELS in the classroom, in particular, instruction through its embedded reading comprehension strategies. Regional sessions were held with teachers from local schools, in the case of San Fernando City (VI region) and Los Andes City (V region); two schools offered their infrastructure to run the sessions. Participant schools from the Metropolitan Region (XIII region) held their sessions at the university conducting the study. The course’s aims were: (1) to recognize the relevance of visual learning strategies in improving reading comprehension, (2) to identify the cognitive skills involved in reading comprehension and their relationship with visual learning strategies, (3) to develop instructional activities relating visual learning strategies included in e-PELS and the development of cognitive skills involved in reading comprehension, and (4) to use e-PELS as a multiple-strategy instructional method.

During the course, we asked teachers to propose improvements to e-PELS. Several changes were suggested and implemented, among them: (a) to use red and blue colors to highlight text (emulating the pencil used by students in schools), and not red and green as included in the original application, (b) to modify and include textual typologies not originally considered, such as dramatic, poetic, informative and news, and to eliminate argumentative text structure, and (c) to add a word-box graphic organizer for word definitions, allowing a structured way to define unknown words.

Twenty-seven elementary school teachers used e-PELS with their students. They were in charge of teaching all subjects required in 4th grade — Spanish, math, social studies science, except arts and physical education. During the course, one of the main difficulties confronted by teachers was their lack of methodological resources to teach reading comprehension. In general, Chilean schoolteachers show a tendency to concentrate extensively on teaching the Spanish language structure (i.e., grammar) and assessing fact memorization; offering few opportunities to teach strategies that foster reading comprehension. These teaching practices have also influenced how educational technology has been developed and implemented in schools, reinforcing the prevailing fact delivery approach. Our main objective was to integrate e-PELS within the Spanish language curriculum. Therefore, teachers were asked to integrate our reading comprehension activities within their semester curricular planning, and to make it effective through their weekly instructional plans.

5.4. E-PELS in the classroom

After the summer school holidays, in March 2009, teachers in the treatment schools were contacted again to initiate the application of e-PELS in their schools. Teachers agreed to follow a 30-session program with their students during the first semester, incorporating each strategy sequentially as indicated in Table 2. At the beginning of the semester, before the implementation of e-PELS, all students took the pretest (CLP form A) to measure their skills in reading comprehension prior to e-PELS implementation; at the end of the semester, in July 2009, students took the posttest (CLP form B) and a test on the strategies included in e-PELS. To avoid any influence on students by their teachers, the research team administered each assessment in every school.

During the semester, teachers in the treatment group taught each of the six strategies included in the program during their regular classes. Each 90-min session took place in the computer lab or in the classroom, with teachers using a laptop and data projector and students using a printed version of each strategy. Only one school had some difficulties with its computer lab, so it used a more intensive in-classroom version of e-PELS. In order to practice with each strategy, teachers were encouraged to give homework with the paper version. For this, additional materials with exercises were provided to teachers, some of them available online, and schools with fewer resources (mainly schools in San Fernando city) were sent the material in printed form. These materials included detailed instructions on how to work with each strategy. Teachers provided guidance and feedback on each strategy and on how to use the software and the complementary instructional material.

Most schools completed 30 sessions of the reading comprehension program as originally established. Some schools completed 35 sessions with e-PELS, combining classroom sessions with computer lab sessions. Only one school (School Nine) was not able to follow the program appropriately due to several causes, among them, a strike that affected schools in region VI. This school was not considered in this analysis. At the end of the semester, students took CLP form B as a posttest and a test on the strategies used.

Table 2
Learning strategies per session.

Session	Activity
Before the 1st session	Pretest (CLP level 3 form A)
1–5	Presentation of e-PELS Highlighting main ideas from the source texts
6–10	Paraphrasing from highlighted text
11–15	Text structures with self-questioning strategy
16–20	Organization and idea production with interactive graphic organizers
21–25	Summary
26–30	Integrated and systematic practice of each strategy included in e-PELS.
After the 30th session	Posttest (CLP level 3 form B) and test on strategies

Table 3

Pretest, posttest, and gain scores for e-PELS and traditional instruction (TI) groups for all students and for key subgroups.

Group		N	Pretest		Posttest		Gain	
			M	SD	M	SD	M	SD
All	e-PELS	742	15.73	3.45	16.53	2.80	.81	3.12
	TI	83	16.93	3.07	16.18	3.37	–.75	3.08
Low-achievers	e-PELS	400	13.19	2.60	15.48	3.03	2.30	3.21
	TI	28	13.64	2.93	14.07	3.40	.43	3.31
High-achievers	e-PELS	342	18.69	1.26	17.76	1.87	–.94	1.88
	TI	55	18.60	1.26	17.25	2.84	–1.35	2.78
Girls	e-PELS	480	16.13	3.20	16.68	2.58	.56	2.96
	TI	52	17.12	2.85	16.42	2.89	–.69	3.09
Boys	e-PELS	262	14.99	3.78	16.25	2.14	1.26	3.35
	TI	31	16.61	3.44	15.77	4.09	–.84	3.10

Schools in the traditional instruction group followed their planned annual curriculum without introducing e-PELS or other computer-based instruction in reading comprehension. The research team assessed students in the traditional instruction group on similar dates as students in the e-PELS group.

6. Findings

The main focus of this study is on comparing the effectiveness of the e-PELS and traditional instruction (TI) groups on their changes in reading comprehension performance. Table 3 summarizes the main descriptive statistics — the pretest score, posttest score, and gain score — for all students in each group on the reading comprehension test, as well as separately for low-achieving and high-achieving students and for boys and girls in each group.³ The median on the pretest was used to differentiate between low- and high-achieving students. The median for all students was 16 points. Students with a score equal to or less than 16 points were regarded as low-achieving students and those scoring above 16 points as high-achieving students. Table 4 shows the effect size of the e-PELS group as compared to the TI group based on pretest score, posttest score, and gain score for all students as well as for low-achievers, high-achievers, boys, and girls separately. Effect size (*ES*) was calculated based on Cohen's *d* (Cohen, 1988) — i.e., the difference in means for experimental and control groups divided by the pooled standard deviation. Sample sizes were included in the computation of *d* to account for unequal sample sizes between the e-PELS group and TI group. In the case of *ES* for gain score, correlations between pre- and posttests were included in their computation (Lipsey & Wilson, 2001). Students who took both the pretest and posttest are included in the analysis since not all students were present at the time the tests were administered; totaling 742 students in the e-PELS group and 83 students in the TI group.

6.1. Do students learn more with e-PELS than with traditional instruction?

As can be seen in top section of Table 3, students in the e-PELS group show a greater pretest-to-posttest gain in reading comprehension score than do students in the traditional instruction group. To examine whether the instructional methods had a differentiated effect on the students, a one-way ANCOVA (with pretest score as a covariate) was carried out due to significant pretest score differences between the groups.

The one-way ANCOVA was used to examine the effects of the instructional methods on reading comprehension scores at posttest while controlling for variations in the pretest. A verification of the assumptions to run an ANCOVA revealed that, first, the relationship between covariate (reading comprehension at pretest) and dependent variable (reading comprehension at posttest) was linear ($r = .511, p < .01$). Second, the Levene's test showed equal variances between groups ($F = 3.493, p = .062$). Third, level of significance for homogeneity of regression was on the limit, consequently, non-significant interaction between reading comprehension at pretest as the covariate and instructional method as the independent variable was assumed ($F = 4.019, p = .045$). Table 5 shows the results of the one-way ANCOVA, which revealed that the e-PELS group significantly outscored the traditional instruction group on reading comprehension posttest score as adjusted for pretest score ($F(1, 824) = 9.363, p = .002$), with $d = .4$. The adjusted posttest means were 16.58 ($SD = 2.45$) for the e-PELS group and 15.71 ($SD = 2.46$) for the traditional instruction group. Thus, this analysis confirms the effectiveness of the e-PELS treatment, when pretest score is controlled. Evidence for significantly higher gain scores and significantly higher adjusted posttest scores for the e-PELS group constitutes the major findings of this study.⁴

6.2. Is e-PELS more effective than traditional instruction for low-achieving students and high-achieving students?

A second question concerns whether the e-PELS treatment is more effective than traditional instruction for various subgroups of students, such as lower-achieving and higher-achieving students. Research and theory in cognitive strategy instruction suggests that direct instruction in cognitive strategies may be more effective for lower-achieving students because they are less likely to develop the needed strategies on their own. Two separate one-way ANCOVAs were conducted to establish whether e-PELS was effective for low- and high-achieving students. In a preliminary analysis evaluating equality of variance assumption for ANCOVA, the Levene's test showed equal

³ The analysis was performed at student level, although students were nested in classrooms and schools. The computation of the intra-class correlation coefficient (ICC) at classroom level resulted in .026; a very small value that justified the analysis at this level (Heck, Thomas, & Tabata, 2010). Similar results were obtained when school level was included (ICC = .035).

⁴ Similarly, an ANOVA analysis over gain scores showed that the e-PELS group outperformed the TI group ($F = 18.506, p = .000$, with $d = .5$).

Table 4
Effect sizes.

Group	Pretest		Posttest		Gain	
	ES	95% CI	ES	95% CI	ES	95% CI
All	-.4	[-.6, -.1]	.1	[-.1, .3]	.5	[.3, .7]
Low-achievers	-.2	[-.6, .2]	.5	[.1, .9]	.7	[.2, 1.1]
High-achievers	.0	[-.3, .2]	.3	[.0, .5]	.2	[-.1, .5]
Girls	-.3	[-.6, .0]	.1	[-.2, .4]	.4	[.1, .7]
Boys	-.4	[-.8, -.1]	.2	[-.2, .6]	.6	[.3, .9]

Note. CI = confidence interval.

variances among low-achieving students for pretest ($F(1, 427) = .003, p = .958$), posttest ($F(1, 427) = .264, p = .607$) and gain score ($F(1, 427) = .058, p = .810$), and for high-achieving students, equal variances for pretest ($F(1, 396) = .036, p = .849$) only. For posttest and gain score, the ratio between group's variances for high-achieving students is just above two, therefore, equality of variance was assumed. Regarding homogeneity of regression assumption, the results indicated no significant interaction between reading comprehension at pretest and instructional method for low-achieving ($F(1, 427) = .299, p = .585$) and high-achieving ($F(1, 396) = .286, p = .593$) students.

The two separate one-way ANCOVAs with pretest score as the covariate and posttest score as the dependent measure (summarized in Table 6) revealed a significant difference on posttest score due to the instructional method for low-achieving students ($F(1, 428) = 8.322, p = .004, d = .6$) but not for high-achieving students ($F(1, 397) = 2.651, p = .104, d = .2$). For low-achieving students, adjusted posttest means were 15.49 ($SD = 2.84$) for the e-PELS group and 13.89 ($SD = 2.85$) for the traditional instruction group; whereas for high-achieving students, the adjusted posttest means were 17.75 ($SD = 1.92$) for the e-PELS group and 17.29 ($SD = 1.93$) for the traditional instruction group. Finally, as expected there was a significant relationship between pretest score (covariate) and posttest score for low-achieving students ($F(1, 428) = 65.794, p = .000$) and high-achieving students ($F(1, 397) = 42.283, p = .000$). Overall, instructional methods accounted for 1.6 percent of the variance in the posttest ($\eta^2 = .016$) for low-achieving students and .7 percents for high-achieving students.

To corroborate these conclusions, a two-way ANCOVA was performed with treatment group and achievement level as factors and posttest score controlled for pretest score as the dependent measure. No significant differences were found among groups (low- and high-achieving) at posttest ($F(1, 824) = 1.388, p = .239$), and there was no significant interaction between instructional method and treatment group on reading comprehension at posttest while controlling for pretest ($F(1, 824) = 3.717, p = .054$). On the other hand, instructional method showed a significant difference ($F(1, 824) = 12.107, p = .001, d = .4$), corroborating that e-PELS benefited both low- and high-achieving students, although the effects were larger for low-achieving students, as demonstrated previously.

6.3. Is the e-PELS treatment more effective than traditional instruction for boys and girls?

A third question is whether the e-PELS treatment is more effective than the traditional instruction treatment for boys and girls. This issue is motivated by the idea that boys may be particularly in need of support in language arts. In a preliminary analysis evaluating equality of variance assumption for ANCOVA, the Levene's test showed equal variances among girls for pretest ($F = 1.560, p = .212$), posttest ($F = 1.383, p = .240$) and gain score ($F = .468, p = .494$), and among boys for pretest ($F = 3.762, p = .053$), posttest ($F = 3.464, p = .064$) and gain score ($F = .754, p = .386$). The results of the two-way ANCOVA with pretest as the covariate and posttest score as the dependent measure (summarized in Table 7) showed a significant main effect for instructional method favoring the e-PELS group ($F(1, 824) = 10.050, p = .002, d = .4$). For girls, the adjusted mean posttest scores were 16.56 ($SD = 2.45$) with e-PELS and 15.87 ($SD = 2.46$) with traditional instruction; whereas for boys, the adjusted mean posttest scores were 16.62 ($SD = 2.48$) with e-PELS and 15.44 ($SD = 2.45$) with traditional instruction. There was no significant instructional method by gender interaction effect on reading comprehension at posttest while controlling for pretest ($F(1, 824) = .700, p = .403$), and thus no evidence that the e-PELS treatment affected boys and girls differently.

6.4. E-PELS's impacts in each classroom

Overall, the major findings reported in the foregoing sections are that a computer-based program for teaching a collection of reading comprehension strategies (e-PELS) resulted in more improvement in reading comprehension performance than traditional instruction, and the effectiveness of e-PELS was particularly strong for lower-achieving students. In this section, the following analysis presents more fine-grained findings on the impacts of e-PELS on each classroom by school. Table 8 displays the average scores on the pretest, posttest, gain score, and correlations for classrooms in the e-PELS group and the traditional instruction group. From twenty-six classes whose students used e-PELS, twenty-four obtained positive gain scores, with only two classes that decreased slightly their average scores. Regarding the traditional instruction group, only one of the classes increased slightly its score, whereas the other two decreased their scores on the posttest.

Table 5
Analysis of covariance for reading comprehension at posttest by instructional method.

Source of variance	SS	df	MS	F	p	Partial η^2	Power ^a
Comprehension pretest	1805.834	1	1805.834	301.385	.000	.268	1.000
Instructional method	56.103	1	56.103	9.363	.002	.011	.864
Error	4925.242	822	5.992				
Total	231231.000	825					
Corrected total	6740.235	824					

^a Computed using $\alpha = .05, R^2 = .273$.

Table 6

ANCOVA for reading comprehension at posttest by instructional method for low- and high-achieving students.

Performance	Source of variance	SS	df	MS	F	p	Partial η^2	Power ^a
Low-achievers ^b	Comprehension pretest	531.899	1	531.899	65.794	.000	.134	1.000
	Instructional method	67.278	1	67.278	8.322	.004	.019	.821
	Error	3435.836	425	8.084				
	Total	105395.000	428					
High-achievers ^c	Comprehension pretest	157.129	1	157.129	42.283	.000	.097	1.000
	Instructional method	9.850	1	9.850	2.651	.104	.007	.369
	Error	1464.164	394	3.716				
	Total	125836.000	397					

^a Computed using alpha = .05.^b $R^2 = .145$.^c $R^2 = .104$.

6.5. Effect size by classroom

Since the foregoing analysis was developed at student level and the findings may have been affected by sample size differences between e-PELS and TI groups, we decided to compute effect sizes at the classroom level. As will be shown in this section, the results at the classroom level were similar to those at the student level that were reported in the previous sections. To do so clusters with comparable classrooms were established using average pretest scores. The grouping was based on the agglomerative hierarchical clustering method (Everitt, Landau, Leese, & Stahl, 2011). Not all classes in the e-PELS group matched classes in the TI group, so the comparison groups were smaller. Table 9 contains the resulting clusters and the respective effect sizes, which were calculated using gain scores to account for pretest differences. Variances (v) were included to estimate average weighted ES .

E-PELS classrooms in each cluster were paired with their respective TI classroom according to the agglomerative hierarchical clustering analysis (see Table 9). Consequently, in relation to the pretest scores, cluster 1 contains the best performing classes, followed by cluster 2 which showed lower pretest scores than cluster 1, and cluster 3 includes classrooms with the lowest scores, with each cluster shown in relation to its corresponding school in the TI group. The effect sizes for cluster 1 are small, showing that for high-achieving classrooms, e-PELS had a small impact. On other hand, clusters 2 and 3 exhibit mostly medium effect sizes, demonstrating that e-PELS appears to have a larger impact on these types of classrooms. In addition, the median effect size for all classrooms was .52.

To summarize and compare the results from the cluster conformations, we ran a meta-analysis with the effect sizes (ES) calculated in the tables above. Results are shown in the Table 10, where unweighted and weighted ES are shown, with their respective standard deviations and 95% confidence interval for the weighted ES . The weighted ES was estimated using a fixed effect model (Borenstein, Hedges & Rothstein, 2009). As shown in Table 10, there are small differences between unweighted and weighted effect sizes in each cluster analyzed. Between cluster differences were significant only in relation to cluster 1 that grouped the best performance classes in our evaluation. These results indicate that direct instruction with e-PELS had the biggest impact on the lowest performing schools, confirming the results presented in the previous sections. Furthermore, the weighted effect size ($ES = .49$) is the same as the effect size for gain score between e-PELS and TI groups as exhibited in Table 4.

6.6. Strategies in e-PELS

Two weeks before the application of the posttest to measure reading comprehension, the learning-strategy test was applied to assess how well students were performing with each strategy included in e-PELS. The test was administered only to schools that used e-PELS in the Metropolitan Region and 425 students responded it. The test on the reading comprehension strategies had a maximum score of 48 points; however, the maximum score obtained by the students was 39 points. The average overall score achieved was 22.64 points, representing a 47.2% of correct answers. A visual representation of the data and the Kolmogorov–Smirnov test ($Z = .893$, $p = .403$) showed that the scores were normally distributed. Table 11 exhibits the average score by school and the percentage of correct answers representing such score.

The analysis also showed a strong association between average scores obtained by each school on the strategy test and the posttest, with a Pearson correlation of .689 ($p = .08$). Schools with a better performance on the strategy test tended to show a better performance on the posttest as well. The following results indicate students' average score on each strategy. Students' lowest performance was on paraphrasing ($M = .360$,

Table 7

Two-way ANCOVA for instructional method by gender interaction effect.

Source of variance	SS	df	MS	F	p	Partial η^2	Power ^a
Pretest	1770.328	1	1770.328	294.993	.000	.265	1.000
Instructional method (IM)	60.312	1	60.312	10.050	.002	.012	.886
Gender (G)	2.374	1	2.374	.396	.530	.000	.096
IM $\times$ G	4.201	1	4.201	.700	.403	.001	.133
Error	4921.024	820	6.001				
Total	231231.000	825					
Corrected total	6740.235	824					

^a Computed using alpha = .05, $R^2 = .270$.

Table 8
Scores by school and class.

School	Class	N	Pre		Post		Gain		Pre/post r
			M	SD	M	SD	M	SD	
School One	A	25	14.92	3.08	15.84	3.01	.92	3.14	.47
	B	32	15.03	3.36	16.50	2.80	1.47	3.09	.51
School Two	A	21	14.38	4.19	14.33	3.62	−.05	3.46	.62
School Three	A	28	15.32	3.24	16.50	2.67	1.18	2.72	.59
	B	29	13.93	4.20	15.31	2.58	1.38	4.10	.35
	C	26	14.58	3.10	16.42	2.32	1.85	3.12	.36
School Four	A	30	15.93	3.70	16.90	3.02	.97	3.01	.61
School Five	A	33	15.76	3.32	17.00	1.95	1.24	3.36	.27
School Six	A	14	15.29	3.60	16.07	4.18	.78	3.40	.63
School Seven	A	20	16.10	3.81	16.35	3.25	.25	2.90	.67
School Eight	A	9	16.44	3.17	17.11	2.32	.67	2.69	.56
School Nine	A	11	12.27	4.76	14.36	3.91	2.09	4.59	.45
School Eleven*	A	18	15.89	3.34	15.17	3.93	−.72	2.89	.70
School Twelve	A	22	15.95	3.40	16.45	2.72	.50	2.92	.56
	B	15	14.27	3.35	15.47	3.68	1.20	4.35	.24
School Thirteen	A	26	13.12	3.73	15.00	3.29	1.88	2.60	.73
School Fourteen*	A	35	17.06	3.07	15.57	3.87	−1.49	3.48	.51
School Fifteen	A	37	16.43	3.06	16.59	2.33	.16	2.96	.42
	B	41	15.32	3.31	16.17	3.01	.85	2.97	.56
School Sixteen	A	31	15.19	3.83	16.39	2.43	1.20	3.71	.36
School Seventeen	A	41	15.44	3.35	16.49	3.26	1.05	2.31	.76
	B	37	16.14	2.92	17.16	2.08	1.02	3.35	.13
School Eighteen*	A	30	17.40	2.86	17.50	1.66	.10	2.51	.49
School Nineteen	A	35	17.37	2.47	17.89	1.94	.52	2.23	.51
	B	41	17.37	2.20	17.46	2.15	.09	2.62	.27
School Twenty	A	34	16.32	3.46	16.53	2.36	.21	3.72	.23
	B	37	16.22	2.74	15.86	2.97	−.36	2.76	.54
School Twenty-one	A	31	17.45	2.84	17.87	2.01	.42	2.72	.41
	B	36	17.33	3.14	18.08	1.71	.75	3.30	.18

Note. Asterisk (*) indicates schools in the traditional instruction group.

$SD = .168$) while their highest performance was on conceptualization ($M = .528$, $SD = .209$), closely followed by graphic organizer strategy ($M = .525$, $SD = .222$), whereas, highlighting ($M = .479$, $SD = .224$) and text structure ($M = .456$, $SD = .206$) strategies obtained similar scores.

As indicated previously, during the implementation process of e-PELS in schools, we found that teachers had some methodological weaknesses regarding how to instruct students on each strategy. This may explain in part why paraphrasing was difficult. Students must elaborate their ideas before writing with their own words what they have understood from the text. Another possible explanation is the tendency by Chilean teachers to assess students based on tests with multiple alternatives, offering few opportunities to develop writing skills. Despite the difficulties with paraphrasing, the other strategies appeared to have evolved positively, principally the use of graphic organizers and the conceptualization strategy, which directly address the development of basic cognitive skills such as comparison, cause-and-effect relationships, sequence, among others.

Table 9
Effect size (ES) for each classroom pair.

Cluster	E-PELS	Class	Traditional instruction					
			School Eighteen		School Fourteen		School Eleven	
			ES	ν	ES	ν	ES	ν
1	School Nineteen	A	.17	.06				
		B	0	0				
	School Twenty-one	A	.13	.07				
		B	.26	.08				
2	School Four	A			.71	.06		
	School Seven	A			.49	.07		
	School Eight	A			.63	.14		
	School Twelve	A			.59	.08		
	School Fifteen	A			.52	.06		
	School Seventeen	B			.82	.08		
	School Twenty	A			.52	.08		
		B			.36	.05		
3	School One	A					.49	.08
		B					.66	.07
	School Three	A					.58	.07
	School Five	A					.63	.08
	School Six	A					.40	.09
	School Fifteen	B					.47	.06
	School Sixteen	A					.56	.08
	School Seventeen	A					.51	.05
		B						

Table 10
Unweighted and weighted effect sizes.

Cluster	N classrooms	Unweighted ES	Weighted ES	SD	95% CI weighted ES	
					LL	UL
1	4	.14	.18	.15	–.11	.48
2	9	.58	.56*	.09	.38	.75
3	7	.54	.54*	.10	.35	.74
Overall	20	.42	.49*	.06	.37	.61

Note. CI = confidence interval; LL = lower limit; UL = upper limit; * $p < .01$.

6.7. Teaching practices

As part of the study, we decided to observe a sample of teaching sessions where e-PELS was integrated as a reading comprehension program, specifically, teachers' instructional methods. Twenty-four sessions were observed in detail and data recorded on a teaching observation form. Ten teachers in seven schools were observed, four of them in three opportunities and six teachers twice. The aspects observed were teaching session organization (opening, development and closing), learning outcomes, time management, classroom management, use of resources and feedback to students. The analysis of the recorded sessions showed that teachers managed relatively well the complementary aspects of their teaching sessions, such as the guided activities to practice each strategy included in e-PELS. They also demonstrated an acceptable use of the software e-PELS when used with the data projector and laptop. Adequate classroom management skills and constant feedback to students on content were observed as well.

The main weaknesses experienced were teaching session organization, its delivery and time management. Teachers showed inconsistent performance regarding session opening, learning outcomes presentation and student motivation. Five teachers had difficulties finding the appropriate teaching methods to relate students' previous knowledge with new content and learning strategies included in e-PELS. In particular, we observed difficulties on instructing how to write small texts and to work with some graphic organizers, such as cause-and-effect and timeline. Regarding session closing, one of the main problems was saving time to review the main aspects taught and learned during each session.

We additionally observed that two out of the six strategies included in e-PELS were relatively easy for teachers to instruct with; these were the word-box that instantiated the conceptualizing strategy and the text structure strategy, particularly, narrative, informative, news, and dramatic structures. We realized that teachers were more familiar with these strategies and associated content, but not so much with how to work with graphic organizers and related cognitive skills. Although highlighting text is straightforward and easy to work with within the software application, at the beginning of the implementation phase, teachers had difficulty in explaining to students how to identify key ideas; and consequently, our research team had to provide additional training on this aspect.

Despite some weakness observed in the instructional methods, teachers and students had the opportunity to develop further their computer related skills. For example, several schools in the e-PELS group integrated online dictionaries to work with the conceptualizing strategy or word-box in e-PELS. One-third of teachers also made intense use of the Internet to look for additional and relevant texts required by e-PELS, such news, dramas and narratives. Schools' administrators realized as well that it was possible to integrate information and communication technologies effectively into the language curriculum, although their support was not always as strong as teachers were expecting.

7. Discussion

A primary objective of this study was to evaluate whether students using e-PELS — a computer-supported multiple-strategy program for reading comprehension — would increase their reading comprehension scores in comparison to students who learned under traditional instruction. Participant teachers in the e-PELS group instructed their students following a structured set of approximately 30 sessions of 90 min each, which were integrated into the Spanish language curriculum. Sessions combined classroom activities using a data projector and computer lab lessons where students interacted directly with the software application as determined by their teachers.

7.1. Empirical contributions

The evidence showed that direct instruction with e-PELS increased students' reading comprehension score more than traditional instruction. Specifically, analyses of pretest-to-posttest gain scores and posttest scores adjusted for pretest score demonstrated that overall e-PELS students significantly improved their reading comprehension level in contrast with TI students. The effect size for all students was $ES = .5$ (as shown in Table 4), which is considered a medium effect size. Similar analysis demonstrated that low-achieving students showed

Table 11
Scores by school on the reading comprehension strategy test.

School	N	Score		Proportion of correct answers	
		M	SD	M	SD
School Thirteen	30	19.40	5.33	.40	.11
School Fifteen	66	20.82	5.28	.43	.11
School Sixteen	31	23.16	5.68	.48	.12
School Seventeen	70	20.49	5.81	.43	.12
School Nineteen	78	27.83	5.64	.58	.18
School Twenty	76	21.66	4.54	.45	.95
School Twenty-one	74	22.93	5.49	.48	.11
Overall	425	22.64	5.98	.47	.13

significant pretest-to-posttest gains, indicating that the strategies included in e-PELS worked particularly well with this group. High-achieving e-PELS students benefited as well, although the differences were not statistically significant compared with TI students. Effect size for low-achieving students (as shown in Table 4) was the largest for the different groups of students analyzed with an $ES = .7$. In the same way, e-PELS boys also benefited with the direct instruction of these strategies, considering that at the beginning of the intervention girls significantly outperformed boys, showing the second largest effect size for the groups examined (as shown in Table 4) with $ES = .6$.

In relation to other studies reported in the literature, computed effect sizes in this study were comparable in magnitude. For instance, Waxman, Lin and Michko (2003) estimated effect sizes for teaching and learning with technology on students' cognitive, affective, and behavioral outcomes. After reviewing 42 studies, they found that the mean study-weighted effect size across learning outcomes was .41 (95% CI .175–.644). For cognitive outcomes in particular, the mean weighted effect size was .45 ($SD = .720$, 95% CI .171–.724), with 29 studies reviewed. More specifically, Murphy et al. (2002) reviewed research that focused on the use of discrete educational software and their effectiveness on student achievement. From such analysis, discrete educational software for reading showed a small to medium positive effect size, with a mean weighted effect size of .35 and a mean unweighted effect of .58. Our results on the use of e-PELS in schools are slightly larger to these findings.

In a different meta-analysis that focused on the use of technology to support reading performance but in middle school grades, Pearson, Ferding, Blomeyer, and Moran (2005) concluded, after reviewing 20 articles that contained 89 effect sizes (i.e.: $N_{ES} = 89$), that the mean weighted effect size was .49. On specific categories analyzed, effect sizes differed, in some occasion significantly. For example, when the studies were designed to improve learning outcomes, such as reading comprehension, the effect size was .41 ($N_{ES} = 34$) whereas those studies concentrating on increasing technology use, the effect size was .36 ($N_{ES} = 30$), compared with those designed to improve achievement gaps, with $ES = .55$ ($N_{ES} = 25$). Regarding assessment type, those studies that employed standardized tests, the effect size was .30 ($N_{ES} = 41$), with larger effects for experimenter-designed tests ($ES = .56$, $N_{ES} = 34$). Additionally, those studies that lasted five or more weeks, the mean effect size was .34 ($N_{ES} = 43$) with larger effects for studies lasting between two and four weeks ($ES = .55$, $N_{ES} = 21$). A significant difference was found with the type of technology used, with a large effect size for those researchers that employed specific-tailored applications, with an $ES = 1.20$ ($N_{ES} = 11$). Meanwhile, the use of commercial packages produced a mean effect size of .28 ($N_{ES} = 34$) in comparison with the use of delivery systems (e.g., electronic texts with a dictionary) that yielded an average effect size of .34 ($N_{ES} = 44$). Compared with this study, the only considerable difference corresponds to effect size for tailored applications, which is larger than the mean effect size for e-PELS.

7.2. Practical contribution

The development of e-PELS as a software application followed a software component approach (D'Souza & Wills, 1998). In other words, each reading comprehension strategy embedded in e-PELS was developed as a separate piece of software — i.e., a component. Each component can operate independently from each other in separate computer environments or they can be integrated into a larger application such as e-PELS. There are several advantages of this approach such as reusability and modularity of each component, which facilitates modification of existing components and development by aggregation and composition of new and more complex applications. For example, e-PELS integrates each strategy in an XML (eXtensible Markup Language) file so modifying its sequence in the main menu or eliminating any of them for a particular instructional activity is relatively simple. This would allow assessing different configurations of reading comprehension strategies and therefore diverse research design and instructional activities tailored to specific educational needs. Alternatively, another option is to develop new strategies as software components and integrate them into e-PELS or similar applications. This would allow assessing new sets of multiple-strategy approaches to reading comprehension in a computer-based environment. Additionally, this software component method allowed teachers to participate in the development process. The original version of e-PELS was modified to satisfy the new requisites from participants teachers, particularly, the incorporation of the conceptualization strategy (it was called “word-box” in e-PELS) and modification of the text type structures originally included. The software alterations only affected those components that implemented the respective reading comprehension strategies, making the development process fast and efficient. Another important advantage of having a series of strategies embedded in a software application such as e-PELS is that it offered teachers a structured way of approaching reading comprehension; a method that they did not have previously.

7.3. Theoretical contribution

Consistent with research on single and multiple-strategy instruction (Dole et al., 2009), this study provides further evidence of their effectiveness but in a computer-based environment. Particularly relevant has been the research on instruction of reading comprehension strategies to target specific content domain (Afflerbach & Cho, 2009; Cook & Mayer, 1988) and research on the use of visual and verbal strategies to foster comprehension (Griffin & Tulbert, 1995; Mayer, 2008). This study contributes new evidence that the systematic translation of texts to visual structures such as graphic organizers and the use of verbal procedures such as paraphrasing and self-questioning foster reading comprehension. This study has additionally offered evidence that such strategies can successfully be embedded into a software application, facilitating the creation of active classroom environments between teachers and their students by providing easy-to-use functionalities that make it possible to concentrate on the reading comprehension process and not on the use of the software, as predicted by cognitive theories of multimedia learning (Mayer, 2009). In the instructional activities implemented in the study, texts are not just presented on the screen for students to read, but with teachers' support, students must actively recognize key ideas (highlighting them), paraphrase such ideas, recognize the overall text structure (i.e., narrative, news, poem) by working directly with visual schemas and self-questioning, and recognize and translate the text into graphic organizers' specific text structures. After such processes have been completed, students can now summarize the text, not by copying part of the original texts, but by creating their personal account of the text. A summary may thus begin by indicating the type of text examined, followed by signaling the key ideas identified, and by elaborating on the specific text structure presented in the original text (e.g., cause-and-effect relationships, comparison-and-contrast structures, sequence of events, among others).

7.4. Limitations and future directions

A first limitation of this study was the large sample size difference between e-PELS students and traditional instruction students, which made some statistical analysis more challenging when the groups were compared directly. The main reason for this difference was that the funding available to run the study only considered funds to work with students that would use e-PELS (a restriction by the funding body). After the funding was granted, the research team was allowed to assign three schools to the traditional instruction group, with naturally each school's previous agreement. Despite this limitation, the main results (Tables 3 and 4) showed an overall similarity when the analysis was performed with pairs of classes (Tables 9 and 10) where sample sizes were comparable.

A second limitation of this study is that the posttest may have used a more difficult form of the reading comprehension test than was used for the pretest, even though both forms were supposed to be equivalent. This problem is mitigated by the fact that our main focus was on differences between the treatment groups on gain scores and on posttest scores adjusted for pretest score, rather than on within group gains per se. A third limitation of this study was that teaching practices in the traditional instruction schools were not systematically observed as teaching practices in the e-PELS schools which may have demonstrated differences in how instruction was performed due the inclusion of this computer-supported program. A fourth limitation refers to maintain issue of introducing a program such as e-PELS. First, several schools continued using the reading comprehension program and its associated software e-PELS since they were given the license. Second, they continued reproducing the printed material developed by the research team. However, one of the difficulties confronted was that schools lacked resources to buy the standardized test used during the study and support staff to help teachers to analyze and interpret the results.

Based on this study, some relevant issues have opened up for further analysis and research. First, although all participant teachers used e-PELS, a notable difference was observed on how they integrated it into their own teaching practices and curriculum. Main deficiencies observed during the study were time management and before-during-and-after reading cycle organization. Should a software application incorporate functionalities to support these processes? Second, schools' management systems and incentives had an influence on how teachers adopted e-PELS, particularly on schools run by municipalities, which showed inflexible and inefficient management practices, making it complicated to interact directly with their management staff. Therefore, how much influence do such management styles have on the implementation of computer-based reading comprehension programs such as e-PELS? Schools run by municipalities exhibited the lowest pretest and posttest scores, although students in such schools increased their reading comprehension level, such improvements could have been certainly higher with the support from the local education authorities. Third, changes on students' cognitive structures and their transfer to other subjects such as history and social studies were not observed during the study. How should such transfer be implemented considering the incorporation of a software application to improve reading comprehension? Finally, the most effective strategies included in e-PELS need to be identified. Students found paraphrasing difficult to assimilate, and teachers had trouble with some graphic organizers that embedded complex cognitive skills.

Overall, this project demonstrates that a well-designed computer-based system that teaches reading comprehension strategies can be used effectively to help elementary school students improve their reading comprehension, adding value beyond traditional classroom instruction on reading comprehension.

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