Reading About Energy:
The Effects of Text Structure in Science Learning and Conceptual Change

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Abstract

The present study investigated the effects of text structure in the acquisition of the concept of energy and the overcoming of specific preconceptions associated with it. Cypriot sixth-grade students read either a simple expository text that presented factual information or a refutation text that, in addition to the factual information, it also explicitly addressed two common preconceptions and proceeded to refute them. Both texts were used as adjuncts to the standard science instruction that is typically provided in the Cypriot elementary school. Students who read the refutation text outperformed students who read the expository text and students who received standard instruction only both in terms of overall learning as well as conceptual change. In contrast, the influence of the expository text was negligible and generally comparable to that of standard instruction. The implications of these results for instructional practice aimed at promoting conceptual change were discussed.

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The recognition that science learning may require conceptual change on the part of the learner has generated a substantial amount of research aiming at the identification of (a) students' alternative conceptions on a variety of science topics (Carey, 1985; Clement, 1982; Vosniadou & Brewer, 1992), and (b) instructional approaches that facilitate the restructuring of alternative conceptions (Diakidoy & Kendeou, 2001; Posner, Strike, Hewson, & Gertzog, 1982; Smith, Maclin, Grosslight, & Davis, 1997). Connected to this latter outcome, has also been the adoption of a constructivist framework as the basis for the quest for more effective instructional interventions. A consequence of this state of affairs has been the move away from the science text (Guzzetti, Snyder, Glass, & Gamas, 1993), and the adoption of more "hands-on" discovery methods and collaborative activities in science classrooms (Driver, Asoko, Leach, Mortimer, & Scott, 1994).

The extent, however, to which a particular instructional method is successful does not necessarily depend on the level of the physical or verbal activity involved or on the ingenuity of the demonstrations utilized. Instead, the important factor must be the level of the mental activity that it entails, as implicated by the basic tenet of constructivism -- namely, that knowledge is not transmitted but actively constructed by the learner. Therefore, any instructional method that has the potential of actively engaging learners in considering their preconceptions in light of scientific models should be a viable candidate for the empirical test. The present study, motivated by the above observations, explored the effects of the use of science text on the learning of one particular science concept, that of energy, and the overcoming of particular preconceptions related to it.

Learning from Text

Text has been and continues to be a primary medium of learning. More importantly, the ability to acquire information from text determines the extent to which an individual can engage in independent, life-long learning (Diakidoy, 1999). Furthermore, in light of current reading comprehension models, the implicit view that text promotes the passive transmission of knowledge is unfounded. All reading research in the last twenty years has conceptualized comprehension as the active construction of meaning, requiring the organization of ideas relative to each other and their integration with prior knowledge (Anderson & Pearson, 1984; Graesser, Swamer, Baggett, & Sell, 1996; Kintsch, 1988; Lorch & Van den Broek, 1997). It is also commonly accepted that the outcome of the comprehension process that can support learning is the construction of a mental representation of text or situation model containing selected text information, relevant prior knowledge, and inferences that reflect the integration of these two sources of information as well as reader-supplied elaborations (Ackerman, 1988; Chan, Burtis, Scardamalia, & Bereiter, 1992; Hamilton, 1997; Kintsch, 1986). Therefore, the extent to which text supports the passive transmission of knowledge should be comparable to that of any other instructional medium, in the sense that it depends on the level or depth of the mental processing that it promotes.

Science text can be readily classified as expository text whose primary function is to inform (Brewer, 1980). As such, it is more likely to contain a substantial amount of unfamiliar information. Therefore, a first obstacle in learning from science text is lack of prior knowledge, a factor that has been shown repeatedly to hinder comprehension (Kim & Van Dusen, 1998; Schnotz, 1993; Spilich, Vesonder, Chiesi, & Voss, 1979). Moreover, as much as lack of knowledge has been found to interfere with comprehension, so have the debilitating effects of incompatible knowledge been documented (Alvermann, Smith, & Readence, 1985; Bartlett, 1932; Lipson, 1982; Woloshyn, Paivio, & Pressley, 1994). Given the findings of conceptual change research, this second factor can be expected to have a prominently negative influence in learning from science text. Finally, the fact that the presentation of information in science textbooks is more likely to resemble that of a series of facts (Eltinge & Roberts, 1993) presents an additional challenge that may thwart readers’ efforts to organize text ideas relative to each other. Therefore, it can be argued that all three factors -- lack of knowledge, incompatible knowledge, and inconsiderate text structure -- conspire to induce only superficial processing of science text that cannot support meaningful learning or the restructuring of preconceptions.

The results, however, of previous research that has explored the effects of different text structures in conjunction with incompatible prior knowledge in science learning have been promising. The study by Maria and MacGinitie (1987) was one of the first to show that a refutational text structure, where a prevalent misconception was acknowledged and directly refuted by preceding or following text information, was more effective with fifth- and sixth-grade students than expository text which simply presented the new information. This facilitative effect of refutation text, as opposed to simple expository or narrative text, has been replicated with high-school students (Alvermann, Hynd, & Quian, 1995; Guzzetti, Williams, Skeels, & Wu, 1997) and college students (Alvermann & Hague, 1989; Hynd, Alvermann, & Quian, 1997; Wang & Andre, 1991). Moreover, the positive effects of a refutational structure were evident even when the to-be-learned information was presented in a single sentence instead of in a longer text (Woloshyn et al., 1994).

The primary characteristic of refutation text that appears to be responsible for its superiority with respect to science learning is the explicit consideration of preconceptions. When compared to the mere presentation of new information, the addition of preconceptions along with related refutational data and explanations functions to elaborate the text. Such text-provided elaborations have been found particularly helpful in the absence of relevant background knowledge with which the new information could be linked (Kim & Van Dusen, 1998). In addition, by addressing preconceptions that learners may share, refutation text directly supports comparisons and may, therefore, reinforce the deeper processing of scientific models.

It must be noted, however, that more pronounced effects have been obtained when a refutational structure was combined with some type of supportive activity, such as small-group discussion after reading (Alvermann et al., 1995), elaborative interrogation, whose function was to induce students to think why the stated fact was true (Woloshyn et al., 1994), or augmented activation of prior knowledge, whose additional goal was to alert students to the fact that what they will read in text may be different from what they know or believe (Alvermann & Hague, 1989). All of these activities were designed to ensure the meaningful processing of new information presented in text. It remains, therefore, unclear the extent to which the facilitation effects of refutation text will be maintained in a less supportive instructional context and with a sample of students not used to reading and learning from science text.

Science instruction in Cypriot sixth-grade classrooms is heavily based on teacher presentation, demonstration, and questioning. Prespecified questions and activities require students to restate concepts and to identify new examples that are, nevertheless, very similar to those presented by the teacher (e.g., Kyprianou, Loizidou, Charalambous, Matsikaris, & Yiannakis, 1997; 1999). Although lessons start with students' ideas, neither students nor teachers are alerted to the possibility of preconceptions. Moreover, students are not familiar with extended science text since the only printed medium used in elementary science classrooms is the Student Workbook (e.g., Kyprianou et al., 1999). The purpose, then, of the present study was to examine the effects of refutation text and to compare them to those of expository text when both are used as adjuncts to the standard instruction typically provided in the Cypriot sixth-grade science classrooms.

Learning About Energy

According to Warren (1982), energy should be banished from the elementary-school curriculum. One problematic aspect about energy is that it represents an abstract, theoretical concept. The scientific conceptualization of energy as the capacity for work (Warren, 1982) implicates that what may be directly observable are only the results of energy storage and transformation, not energy itself. Previous work on abstract physics concepts has unveiled students' tendency to conceptualize such concepts as representing material entities (Reiner, Slotta, Chi, & Resnick, 2000). More importantly, however, Kruger, Palacio, and Summers (1992) identified a similar tendency in primary-school teachers with respect to energy. Teachers' preconceptions are not only a serious source of concern in and of themselves, but they may also combine with the curriculum, contributing further to their entrenchment in teachers and students alike.

Energy, for example, in the Cypriot elementary school is formally taught in the sixth grade in the course of three lessons focusing in its forms, transformations, and sources (Cypriot National Curriculum, 1996). The introduction in the Science Teachers' Manual (Kyprianou et al., 1997) warns teachers at the outset that energy cannot be easily defined (p. 227). It immediately proceeds, however, to explain that "energy exists in nature" (p. 227) "in large quantities" (p. 230). At the same time, the closest to a definition that teachers - not students - get to read is that "energy is used when work is produced" (p. 227). While language may inadvertently permit analogies to be formed between energy and material entities or properties, we consider the lack of reference to its abstractness more serious because it can effectively block even the beginning of thinking about energy as different from matter.

Another potential preconception that is more obviously related to and reinforced by language is the conceptualization of energy as force (Duit, 1984; Ioannides & Vosniadou, in press; Kruger et al., 1992). In the Greek language, which is the language of instruction in the Cypriot school, a single word - dynamis - is used to denote both strength and force. Moreover, it is common in everyday speech to refer to adults as exerting more force when lifting or pushing objects because they have more strength than children. At the same time, it is also common to refer to adults as exerting less force because they exert less effort than children (Ioannides & Vosniadou, in press). Consequently, the unelaborated presentation of the scientific conception of energy as the capacity for work may give rise to the understanding of energy as physical strength. In turn, given the undifferentiated vocabulary, energy may be further confused with force itself.

Energy in the sixth-grade science curriculum is explicitly presented as the cause of "movement against friction, resistance, and gravitational force" (Kyprianou et al., 1997, p. 227). Students, however, have also encountered force as the cause of movement and acceleration in Grades 3 and 4 (Cypriot National Curriculum, 1996). An examination of the information contained in the Science Teachers' Manual and the Student Workbook (Kyprianou et al, 1997;

1999) indicates that this is neither taken into account nor is the missing link that could help distinguish energy from force provided anywhere. The activation, therefore, of that knowledge and the integration of the new information with it - which would, after all, constitute meaningful processing on the part of the students - might easily lead to the conclusion that energy and force represent essentially the same concept.

The materialistic conception of energy and its confusion with force are not the only preconceptions that may hinder the understanding and learning of the concept of energy. They were, however, the focus of the present study. Specifically, we wanted to assess the extent to which the use of refutation text would help students overcome these preconceptions. In addition, we wanted to compare its overall effectiveness to that of simple expository text and standard instruction. All students in the sample received standard instruction on energy in the manner and timing suggested by the Cypriot National Curriculum (1996) and the Science Teachers’ Manual (Kyprianou et al., 1997). Subsequently, one third of the students read a refutation text whose function was to address the target preconceptions and to provide a review of the lesson. Another one third of the students read an expository text whose sole function was to provide a review. The rest of the students, who received standard instruction only, comprised the control group. Students’ learning was assessed one day after instruction and, again, one month later. We hypothesized that students who read a refutation text as an adjunct to the standard instruction will show more overall learning and will be less likely to confuse it with force or material entities as opposed to students who read the simple expository text and students who receive standard instruction only. We also hypothesized that students who read either type of text will show more overall learning than students who read no text. Finally, we expected any effects with respect to learning or the target preconceptions to maintain over time.

Method

Participants

The participants were 215 sixth-grade students (109 males and 106 females) from six rural schools in the island nation of Cyprus. There were two sixth-grade classrooms in four of the schools and one sixth-grade classroom in each of the other two schools. For the purposes of the study, the students remained in their intact classrooms. All students' native language was Greek. Individual Analyses of Variance indicated that there were no significant differences between Schools or between Classrooms within Schools with respect to Grade Point Average, Science Grade, and Reading Grade ($p < .05$). Means and standard deviations of preliminary measures can be seen in Table 1.

Each classroom was randomly assigned to one of two experimental instruction groups ($n = 77$ and $n = 76$ respectively) or to a Standard Instruction Group ($n = 62$) that served as the control. Means and standard deviations of preliminary measures within each Instruction Group can be seen in Table 2. Analyses of Variance indicated that there were significant differences between the Instruction Groups with respect to Science Grade, F (2, 212) = 3.81, $p = .02$. Multiple comparisons indicated that the Standard Instruction Group had a significantly higher Science Grade Mean than the Refutation Text Group ($p < .05$). Although this result reflects an advantage of the control group over the experimental groups, we decided against altering the groups' composition, opting for a more stringent test of our main hypothesis.

Materials

The materials utilized for instruction in all groups were a) 30 picture cards depicting sources of energy; b) a piece of paper folded in half with the ends of a twisted rubber band glued on the inside and a wooden match inserted in the middle of the twisted rubber band; c) a closed electric circuit consisting of a battery, a small lamp, and two wires; and d) the section on Energy in the Science Workbook (Kyprianou et al., 1997) which included two activities to be completed by the students.

Expository text. A 522-word long expository text on energy was written. It included three sections focusing on energy sources and forms, and energy transformation and storage. The purpose of the expository text was to provide a review of the concepts covered during instruction and to draw students' attention to main ideas.

<u>Refutation text</u>. A 1039-word long refutation text including four sections was also written (see Appendix A). Its content and purpose were similar to those of the expository text. In addition, the refutation text focused on two potential preconceptions, namely the lack of differentiation between the concepts of Energy and Force and the conceptualization of energy as a substance with material properties. Therefore, its additional purpose was to prevent the formation and/or to facilitate restructuring of these alternative conceptions.

<u>Energy Test</u>. The primary purpose of the Energy Test was to assess the acquisition of the instructed concepts. However, it also included groups of items that targeted the two selected preconceptions. Therefore, its purpose was also to reveal the extent to which students were able to differentiate between energy and force and the extent to which they attributed material properties to energy as a result of text reading and instruction.

The Energy Test included a total of 16 items and was divided in two parts. Part A included six short-answer questions, while Part B included four forced-choice items and six yes/no questions (see Appendix B). Overall, four items focused on the distinction between energy and force while three items focused on the immaterial nature of energy. The rest of the items were designed to assess learning of the different forms of energy and their characteristics.

Nine of the 16 items were completely inferential in the sense that their answers were not stated explicitly in any of the experimental texts and had not been mentioned or discussed during instruction. Three items represented text-inferential questions, while two items represented lesson-inferential questions. The remaining two items were completely literal in the sense that their answers had been stated explicitly in the texts and during instruction. Although the inclusion of the two lesson-inferential items may have given an advantage to the experimental groups over the control, we reasoned that any increases in performance due to their inclusion would be small and more likely to dissipate over time.

Responses to the Energy Test were scored dichotomously. Each correct response received a score of 1, while each incorrect response received a score of 0, and raw scores were converted into proportions. The scoring procedure yielded one Energy Total Score for each student which served as the primary dependent variable. In addition, subtotal scores in groups of items - Energy/Force and Energy/Material - were also computed in order to assess students' understanding with respect to the target preconceptions.

The reliability of the Energy Test was modest (KR-20 = .55) but acceptable given the purpose of the study (Nunnally, 1978). It must be noted, however, that a low reliability coefficient was expected because of the inclusion of distinct groups of items. Given our sample's novice status and the conceptual level targeted by instruction, there was no basis to expect that a particular concept assessed by a group of items will serve as prerequisite and, therefore, relate to the acquisition of the other concepts. In fact, a correlation analysis indicated that while performance on both the Energy/Force items and the Energy/Material items related to students' learning of the instructed concepts (Energy/Forms), performance with respect to one preconception was relatively independent of performance with respect to the other (Table 3).

<u>Procedure</u>

The study was conducted in three phases. In Phase 1, two separate group meetings were conducted, first with the teachers whose classrooms were assigned to the Standard Instruction Group, and, second, with the teachers whose classrooms were assigned to the Experimental Instruction Groups. The purpose of these meetings was to inform the participating teachers about the general purpose of the study, the timetable, and the general procedures to be followed. One month later, individual follow-up meetings were held with each participating teacher in order to further specify instructional procedures and to finalize lesson plans according to Instruction Group assignment.

Phase 2, the instructional phase, took place three weeks later. Instruction of the concept of Energy was carried by the regular classroom science teacher and observed by the second author in order to ensure that there would be no instructional differences between classrooms other than those introduced by the study. Instruction was completed within an 80-minute lesson period in all classrooms, regardless of Group assignment.

Standard Instruction Group. The instruction in the Standard Instruction Group followed the guidelines specified in the Science Teachers’ Manual (Kyprianou et al., 1997). Instruction was based primarily on teacher questions and presentations. The lesson was divided into three parts: introduction, main part, and review.

In order to introduce the concept of Energy, the teacher asked students to think and say what the term Energy meant to them. Then s/he presented and discussed magazine pictures related to the production and consumption of energy. The introduction was completed by having students to think of activities that require energy in order to be performed.

Subsequently, students completed the first two activities in their Science Workbook (Kyprianou et al., 1997). The first activity required students to rate sets of four pictured appliances, foods, and sources of energy with respect to the amount of energy required to operate, given, and stored respectively. The second activity required students to think and write a) things they do every day that require energy, b) house appliances that require energy to operate, and c) sources of energy. Students’ answers to the two activities were presented in class and discussed by the teacher.

The students were, then, given a set of 30 picture cards and asked to work in pairs. Their task was to classify all pictures according to the form of energy associated with it - thermal, chemical, light, acoustic, electrical, elastic, and kinetic energy. The results of this activity were also discussed in class, and the teacher asked students to think which of the mentioned forms of energy can be stored. In order to demonstrate the effects of energy storage, the teacher presented the folded paper and the closed electric circuit. The paper was unfolded slowly making the twisted rubber band turn the match attached to it. Similarly, the electric wire was attached to the battery turning on the lamp.

The lesson was completed with the set of review questions suggested in the Science Teachers’ Manual (Kyprianou et al., 1997). Students were asked to mention the forms of energy discussed and those that can be stored and to identify the forms of energy associated with a new set of pictures.

Expository Text Group. Instruction in the Expository Text Group followed the same format as instruction in the Standard Group except that the first activity was omitted, and the review part of the lesson was substituted by the reading of the Expository Text on energy. The first activity (rating of pictured objects according to amount of energy required, given, or stored) was deemed irrelevant to the main instruction topic (energy and its forms) and arbitrary given that sixth-grade students have not been introduced to concepts related to the measurement of energy. Overall, the introduction, the remaining activities and the demonstrations were completed in 50 minutes. Subsequently, students were given the Expository Text and were asked to read each section silently. In order to ensure that all students were engaged to the task, at the end of each section, the teacher asked students to state the main points and/or to summarize the section's information.

Refutation Text Group. Instruction in the Refutation Text Group followed the same procedures as instruction in the Expository Text Group. However, the first two parts of the lesson were completed within 40 minutes as a result of reducing the time allowed for teacher questions. The lesson ended with the reading of the Refutation Text and the summarizing of the information presented in each of its sections.

Phase 3, the testing phase, took place one day after instruction. The Energy Test was administered, and students were instructed to read each statement carefully and to either write their answer on the blank provided or to circle the correct answer. Part A of the Energy Test, was administered first in order to prevent the forced-choice items in Part B from influencing students' short answers. The Energy Test was administered again one month later.

Results

Preliminary analyses indicated that Grade Point Average, Science Grade, and Reading Grade were all positively correlated with each other ($p < .01$). However, it can be seen from Table 4 that only Grade Point Average and Reading Grade were consistently and significantly related to all dependent variables (Table 4). Therefore, Grade Point Average, as the most inclusive measure, was used in all subsequent analyses.

The primary dependent variables, Immediate Energy Total Score and Delayed Energy Total Score, were normally distributed (skewness < 1), and their variances were homogeneous across Instruction Groups ($p > .05$). All the secondary dependent variables were also normally distributed (skewness < 1). However, the variances of Delayed Energy/Force Score were not homogeneous (Cochran's $C = .506$, $p = .001$). Therefore, this variable was excluded from all parametric analyses.

The means of all dependent variables across Instruction Groups are shown in Tables 5 and 6. Overall, it can be seen that the performance of the Refutation Text Group was higher than that of either the Expository Text Group or the Standard Instruction Group. In addition, all groups' performance was higher on the Delayed Energy Test than their performance on the Immediate Energy Test, paired $t(206) = -2.04$, $p = .028$ (Tables 5 and 6).

Multivariate Analysis of Covariance, with Immediate Energy Total Score and Delayed Energy Total Score as the dependent variables, Instruction Group as the independent variable, and Grade Point Average as the covariate, indicated that both the effects of Grade Point Average and Instruction Group were significant: Hotelling's $T^2 = .463$, $F(2, 202) = 46.777$, $p = .000$ and Hotelling's $T^2 = .207$, $F(4, 402) = 10.419$, $p = .000$ respectively. Individual Analyses of Variance, with Grade Point Average coded as a categorical variable, indicated that only the main effects of these variables were significant for both Immediate and Delayed Energy Tests (Table 7). With respect to the Instruction Group effect, multiple comparisons (Scheffe method) showed that the performance of the Refutation Text Group on the Immediate and Delayed Energy Tests was significantly higher than the performance of both the Expository Text Group - d (immediate) = .875 and d (delayed) = .688 - and the Standard Instruction Group - d (immediate) = .875 and d (delayed) = .867. On the other hand, the overall difference between the Expository Text Group and the Standard Instruction Group was not significant (Scheffe method $p > .05$), with the Expository Text Group's performance being lower than that of the

Standard Instruction Group on the Delayed Energy Test, d (delayed) = .133 (see also Tables 5 and 6).

In order to examine the extent to which the reading of text had any effects on overcoming particular preconceptions, Multivariate Analysis of Covariance, with Energy/Force Score, Energy/Material Score, and Energy/Forms Score on the Immediate Test as the dependent variables, was performed. Overall, the effects of Grade Point Average and Instruction Group were significant, Hotelling's T^2 = .218, F (3, 206) = 14.942, p = .000 and Hotelling's T^2 = .410, F (6, 410) = 14.014, p = .000 respectively. However, individual Analyses of Variance indicated that the main effect of Instruction Group was significant only with respect to Energy/Force Score and the Energy/Material Score (see Table 8). Performance of the Refutation Text Group on the Energy/Force items was significantly higher than performance of either the Expository Text Group or the Standard Instruction Group (Scheffe method $p < .05$, d = 1.087 and d = 1.348 respectively). In contrast, performance of the Expository Text Group was not significantly different from that of the Standard Instruction Group (Scheffe method $p > .05$, d = .261). On the other hand, performance of the Refutation Text Group on the Energy/Material items was significantly higher than that of the Expository Text Group only (Scheffe method $p < .05$, d = .424).

Finally, Multivariate Analysis of Covariance indicated that only Grade Point Average had a significant effect on Energy/Material Score and Energy/Forms Score on the Delayed Energy Test, Hotelling's T2 = .224, F (2, 204) = 22.879, p = .000 (see also Table 9). However, a Kruskal-Wallis test showed that the differences between the Instruction Groups were still significant for the Energy/Force items, χ^2 (209) = 67.185, p = .000. Specifically, 87% of the students in the Refutation Text Group responded correctly to all of the Energy/Force items on the Delayed Energy Test in comparison to 32% of the students in the Expository Text Group and 55% of the students in the Standard Instruction Group who similarly gave correct responses.

Discussion

Overall, the findings of the present study confirmed our main hypothesis by highlighting the superiority of a refutational text structure in science learning and conceptual change. Sixth-grade students who read a refutation text as an adjunct to standard instruction outperformed students who read a simple expository text and students who received no text. These findings are in agreement with previous research examining the contribution of refutational text structures in the acquisition of counterintuitive science concepts. In contrast, however, the refutation text employed in this study was longer, addressed more than one preconception (Maria & MacGinitie, 1987; Woloshyn et al., 1994), and was not accompanied by constructive activity designed to support conceptual change (Alvermann & Hague, 1989; Alvermann et al., 1995; Hynd et al., 1997; Woloshyn et al., 1994). It, nevertheless, appeared to be more likely to induce the higher level processing necessary for learning from text (Chan et al., 1992) than the shorter expository text.

It is also notable that, in this case, the refutation text was effective with a sample of students unfamiliar with science text and its structure (e.g., Cook & Mayer, 1988). All science instruction in the Cypriot elementary school (Grades 1 to 6) relies exclusively on teacher presentation and workbook assignments. Understanding and learning from science text is not included as an objective of elementary science instruction (Cypriot National Curriculum, 1996). The inclusion, however, of comparison/contrast elements that characterized the structure of the refutation text appeared to have helped students activate their preconceptions and compare them to the scientific conceptions presented in the text. As a result, they were better able to distinguish concepts that previous research has shown to be commonly confused with each other (e.g., Ioannides & Vosniadou, in press; Kruger et al., 1992).

In comparison, the simple expository text employed in this study was generally ineffective. The performance of students who read the expository text was not significantly different from the performance of students who received standard instruction only. The expository text was constructed to exhibit a factual presentation format with embedded classification elements (Cook & Mayer, 1988) resembling, thereby, the structure characterizing the majority of science textbooks (Eltinge & Roberts, 1993). In this respect, it was similar - and, therefore, redundant - to the standard instruction provided and whose objective was also the simple acquisition and classification of new science concepts. In the absence of any other stimuli or activities both types of presentation, oral or printed, appear to be equally inefficient in supporting deeper processing and the integration of new scientific information with prior, incompatible knowledge.

The findings of the present study may appear to be inconsistent with those of the Mayer, Bove, Bryman, Mars, and Tapangco (1996) study, where a summary was found to be more effective than a 600-word long text. There are, however, important differences between the two studies that can account for any inconsistencies. In a series of three experiments, Mayer et al (1996) examined the contribution of a multimedia summary in the understanding of the cause and effect sequence that gives rise to lightning. In contrast, our study focused on the acquisition of an abstract concept that cannot be easily described or explained in a series of illustrations and short sentences, and whose understanding requires the restructuring of incompatible prior knowledge. Moreover, the purpose of the passage employed by Mayer et al. (1996) was to present factual information and explanations and, therefore, resembled our simple expository text which was also found to be relative ineffective. We do believe, however, that if it were possible to employ the type of summary utilized by Mayer and his colleagues, or if we had opted to include additional interventions, such as scaffolded discussion of text ideas (Alvermann et al., 1995), performance levels would have been higher.

In fact, overall performance was low regardless of instructional condition, and the positive influence of the refutation text was more apparent in relation to that of the expository text and the standard instruction. In addition to the lack of any other intervention, this may also be attributable to the elusive nature of the target scientific concept. Energy represents a

theoretical construct that cannot be directly observed, and, yet, it can be stored. Modern environmental concerns have made energy the subject of our everyday conversation.
We speak of energy conservation and loss, and, yet, it can be transformed from one form to another. And, although a variety of natural phenomena are attributed to energy transformation, the actual process does not lend itself to a clear and explicit description or depiction of the cause and effect sequence (e.g., Mayer et al., 1996). Moreover, our instructional intervention took place on students' first formal encounter with the scientific concept of energy and its forms.
That first lesson was followed by two more lessons on energy transformation and sources, and the three-lesson sequence was completed within one week. Therefore, students had additional opportunities to process the targeted concepts, and that, in turn, may have been responsible for the increased performance on the delayed energy test relative to the immediate test that was administered one day after instruction.

We must also emphasize that the positive influence of the refutation text was more evident in the overcoming of the particular preconceptions that it addressed than in the acquisition of the concepts targeted by standard instruction. Generally, this finding is in agreement with the purpose of its use. More specifically, however, the refutation text gave students the sole opportunity to explicitly compare their own conceptions to scientific ones. Although standard instruction encouraged the activation of prior knowledge, it proceeded to largely ignore it, since there were no guidelines on how to take it into account (Kyprianou et al., 1997). Given that prior research has shown that the mere activation of incompatible knowledge can be detrimental to science learning (e.g., Alvermann & Hague, 1989), standard instruction may have served to further highlight the effectiveness of the refutation text.

We consider the findings of this study especially important from an educational perspective. Conceptual change research has contributed extensively to our knowledge of how novices may conceptualize and explain physical phenomena. Refutation text can incorporate and take advantage of this knowledge providing, thereby, an efficient, yet effective, way of addressing preconceptions and inducing cognitive conflict. The usefulness of refutation text is magnified if we consider that (a) the abstract, theoretical nature of many science concepts renders them unlikely to be discovered through direct observation and experimentation (Driver et al., 1994; Reiner et al., 2000); and (b) teachers themselves may harbor preconceptions that are likely to prevent or undermine any efforts to increase students' understanding (Kruger et al., 1992). Finally, the strategic use of refutation text in the elementary school may also contribute to students' ability to learn from text (Cook & Mayer, 1988) which, in turn, can lay the foundations for future independent science learning.

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Table 1

Means of Grade Point Average (GPA), Science Grade (ScGrade), and Reading Grade (RdGrade) in Groups of School and Class

	GPA[a]	ScGrade[a]	RdGrade[a]
School 1			
(n = 28)	16.46 (3.02)	14.07 (4.69)	16.29 (2.95)
School 2			
(n = 20)	15.95 (3.68)	15.80 (4.46)	16.10 (3.54)
School 3			
Class 1 (n = 25)	14.76 (3.06)	14.84 (2.67)	15.04 (3.26)
Class 2 (n = 24)	13.38 (3.76)	13.25 (3.65)	13.96 (3.58)
School 4			
Class 1 (n = 17)	14.76 (3.11)	13.82 (3.07)	14.29 (2.99)
Class 2 (n = 18)	15.50 (2.57)	13.50 (2.33)	15.89 (2.47)
School 5			
Class 1 (n = 23)	14.00 (3.69)	14.26 (3.20)	14.35 (3.77)
Class 2 (n = 18)	15.56 (2.66)	14.83 (3.36)	15.78 (2.62)
School 6			
Class 1 (n = 21)	15.43 (3.31)	14.86 (3.90)	15.62 (3.31)
Class 2 (n = 21)	15.29 (2.90)	16.10 (3.51)	15.43 (3.28)

Note. Standard Deviations are shown in parentheses.

[a] Maximum score = 20.

Table 2

Means of Grade Point Average (GPA), Science Grade (ScGrade), and Reading Grade (RdGrade) in Instruction Groups

	GPA[a]	ScGrade[a]	RdGrade[a]
Refutation Text (n = 77)	14.95 (3.48)	14.06 (3.81)	15.16 (3.36)
Expository Text (n = 76)	14.89 (3.10)	14.12 (3.01)	15.04 (3.10)
Standard Instruction (n = 62)	15.55 (3.26)	15.58 (3.94)	15.71 (3.33)

Note. Standard Deviations are shown in parentheses.

[a] Maximum score = 20.

Table 3

Correlations Between Scores on Groups of Items on the Immediate and the Delayed Energy Tests

Group Scores	1	2	3
	Immediate Energy Test (N = 212)		
1. Energy/Force	--	.12	.14 *
2. Energy/Material		--	.29 **
3. Energy/Forms			--
	Delayed Energy Test (N = 209)		
1. Energy/Force	--	.12	.25 **
2. Energy/Material		--	.26 **
3. Energy/Forms			--

* $p < .05$. ** $p < .01$.

Table 4

Correlations of Grade Point Average (GPA), Science Grade (ScGrade), and Reading Grade (Rdgrade) With Energy Total Score, Energy/Force Score, Energy/Material Score, and Energy/Forms Score

	Energy/Force	Energy/Material	Energy/Forms	Energy Total
Immediate Energy Test (N = 212)				
GPA	.17 *	.24 **	.38 **	.41 **
ScGrade	.12	.29 **	.39 **	.41 **
RdGrade	.18 **	.22 **	.36 **	.39 **
Delayed Energy Test (N = 209)				
GPA	.27 **	.26 **	.49 **	.52 **
ScGrade	.20 **	.29 **	.51 **	.51 **
RdGrade	.24 **	.26 **	.48 **	.50 **

* $p < .05$. ** $p < .01$.

Table 5

Means of Immediate Energy Test Scores Across Instruction Groups

	Instruction Group		
	Refutation Text	Expository Text	Standard Instruction
Variable	(n = 76)	(n = 74)	(n = 62)
Energy/Force	.68 (.24)	.43 (.23)	.37 (.23)
Energy/Material	.74 (.30)	.60 (.33)	.67 (.33)
Energy/Forms	.47 (.18)	.43 (.16)	.43 (.18)
Energy Total	.63 (.16)	.49 (.13)	.49 (.16)

Note. Standard Deviations are shown in parentheses.

Table 6

Means of Delayed Energy Test Scores Across Instruction Groups

	Instruction Group		
	Refutation Text	Expository Text	Standard Instruction
Variable	(n = 72)	(n = 75)	(n = 62)
Energy/Force	.66 (.29)	.27 (.22)	.39 (.18)
Energy/Material	.78 (.28)	.72 (.33)	.67 (.29)
Energy/Forms	.52 (.18)	.52 (.19)	.51 (.18)
Energy Total	.65 (.18)	.50 (.16)	.52 (.15)

Note. Standard Deviations are shown in parentheses.

Table 7

Analyses of Variance for Immediate and Delayed Energy Tests

Source	df	F	p
	Immediate Energy Test (N = 212)		
Grade Point Average	1	44.573	.000
Instruction Group	2	17.968	.000
GPA x Instruction	2	.597	.551
	Delayed Energy Test (N = 209)		
Grade Point Average	1	51.885	.000
Instruction Group	2	12.342	.000
GPA x Instruction	2	.225	.799

Table 8

Analyses of Variance for Energy/Force, Energy/Material, and Energy/Forms Scores on Immediate Energy Test (N = 212)

Source	df	F	p
	Energy/Force		
Grade Point Average	1	6.798	.010
Instruction Group	2	38.469	.000
GPA x Instruction	2	2.093	.551
	Energy/Material		
Grade Point Average	1	18.717	.000
Instruction Group	2	3.903	.022
GPA x Instruction	2	.367	.693
	Energy/Forms		
Grade Point Average	1	28.311	.000
Instruction Group	2	1.987	.140
GPA x Instruction	2	.758	.470

Table 9

Analyses of Variance for Energy/Material and Energy/Forms Scores on the Delayed Energy Test (N = 209)

Source	df	F	p
	Energy/Material		
Grade Point Average	1	14.333	.000
Instruction Group	2	2.704	.069
GPA x Instruction	2	.597	.553
	Energy/Forms		
Grade Point Average	1	38.514	.000
Instruction Group	2	.244	.784
GPA x Instruction	2	.225	.337

Appendix A

Refutation Text

Energy

Is it energy or force?

From today’s lesson we conclude that a body has energy when it has the capacity to do something. People, for example, have energy because they can move, push, or lift things. In everyday conversation, when we say that people have force[1] we mean the same thing. We also say that whoever can lift heavier things has more force. Are energy and force the same thing?

Before we answer that question let us consider another one first: Suppose that an adult and a child lift a heavy bag. Do they exert the same force? Some people might say that the adult exerts a smaller force because s/he tries less than the child. Others might say that the adult exerts greater force because s/he has more force than the child. That is, they mean that force is something we have inside us. Finally, others might say that the adult and the child will exert the same force because by the word “force” they mean the reason that causes the bag to rise above the floor. So they think that, regardless of who lifts the bag, the result is the same. Since the result is the same then the reason that caused it, that is, the force exerted, is also the same.

These three different answers are due to the fact that we use the word “force” to mean different things. Scientists, however, have decided to distinguish words and meanings in order to communicate better. So, they use the word “energy” to mean the capacity to do something. They use the word “force” to mean the cause that makes immobile objects move or moving objects change their velocity. And they distinguish force from physical, muscular force and effort which they use the same way we do: to express the difficulty we experience when doing something.

Then, how would scientists answer our question? They would say that both the adult and the child have energy. This energy gives them the capacity to exert force on the bag. The force they exert is what causes the bag to be lifted off the floor. The bag’s weight does not change.[2] So, if both the adult and the child lift it, then they would both have exerted equal force.

Energy is consumed[3] and replenished

Let’s take our previous question and rephrase it: Will the adult and the child consume different amounts of energy in order to lift the bag? Scientists would again have answered no for the following reason: The cause behind force exertion is the consumption of energy. So, if the adult and the child exert equal force, then they must also consume equal amounts of energy. In everyday conversation we say that our force is lost when we get tired, and that we eat in order to replenish it. In contrast, scientists say that our energy is consumed, and that we eat in order to replenish it with the energy contained in food.

The same happens with cars and many other machines. In order to move or operate, they consume fuel that contains energy. Batteries, which make our toys work, also contain energy. When we say that the battery is dead we mean that the energy that it contains is consumed. In order to replenish the energy that was consumed and make the toy work again, we must replace the battery.

Energy forms

All bodies have energy but for different reasons and of different type. All moving objects have kinetic energy because they can hit other objects. Energy contained in food, fuel, and batteries is called chemical energy. The reason it is called chemical energy is that there must be some chemical reaction for the energy to be released and make living organisms and machines function. Rubber and springs have possess elastic energy when they are stretched or compressed. If we let them loose, then they move in order to come back to their original length.

Also all bodies, animate or inanimate, hot or cold, have thermal energy. The higher the temperature the higher the thermal energy they possess. We realize this energy when it is transferred from one body to another. So, a light bulb has thermal energy when it is lit because it can warm up our hands. The bulb, however, emits also light energy because it can brighten up a room. Finally, other forms of energy are acoustic energy carried by the sound and electric energy that makes appliances work.

These various forms of energy have different characteristics. There are energy forms that are produced and stored in bodies, such as chemical, thermal, and elastic energy. In contrast, light energy and acoustic energy cannot be stored. They are produced and emitted. Finally, thermal energy is produced, transferred from one body to another, and can even be stored in bodies covered with insulating materials.

Energy is not a substance

It is important to note that, although we talk about energy as if it is something that we can see or eat, energy is not a material entity that we can perceive directly through our senses. For example, by looking at an apple we can see the peel and the seeds. But we cannot see the chemical energy that it contains and that we get when we eat it. The reason is that energy is not a material thing. It is a very useful scientific idea that helps us describe and explain changes that we observe in the physical world. As you learn more about science, you will understand better how useful the concept of energy is.

Appendix A Footnotes

[1] The word “force” is used, sometimes incorrectly, throughout the English version of the refutation text. The purpose was (a) to demonstrate the difficulty that a Greek-speaking reader would have in understanding and distinguishing the concepts of force and energy, and (b) to provide as literal a translation as possible.

[2] The fact that force depends also on the acceleration ($\underline{f} = \underline{m} \times \underline{a}$) was omitted on purpose in order to not detract students from the focal distinction between energy and force.

[3] To speak of energy consumption instead of transfer and/or transformation is acceptable only to the extent that the entire system of interactions between animate and inanimate bodies has not been considered yet.

Appendix B

Energy Test

Part A

1. Why is it that sometimes we cannot run as fast as other times?

2. In a closed electric circuit, what form of energy does the battery have?

3. In a closed electric circuit, what form of energy does the battery produce?

4. A very strong man has a lot of ______________.

5. Suppose a loaf of bread has just been taken out of the oven. What forms of energy does it have?

6. Suppose a cat steals the fish from the barbecue and runs to escape. What forms of energy does the fish have?

Part B

1. An adult and a child will consume

a) equal amounts of energy b) different amounts of energy

when lifting a heavy box.

2. A fire place produces

a) more energy b) less energy

than a lamp.

3. If we use a very strong microscope, can we see the energy contained in gasoline?

a) yes b) no

4. Scientists say that not all foods contain the same amount of energy. Do they know that from measuring energy with special weight scales?

a) yes b) no

5. The forms of energy that are more likely to be stored are chemical and elastic energy.

a) yes b) no

6. Can we take out the energy contained in a fuel and store it elsewhere?

a) yes b) no

7. A car, in order to operate, requires

a) chemical energy b) kinetic energy

8. Two cars, the same model and with the same number of passengers travel down the highway. Car A travels with a speed of 70 km/hour while Car B travels with 100 km/hour.

a) Car A has more kinetic energy b) Car B has more kinetic energy

9. When we eat, do we replenish our lost force?

a) yes b) no

10. Is chemical energy emitted?

a) yes b) no