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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 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. In contrast, the influence of the expository text was negligible and generally comparable to that of standard instruction. The implications of these results for the instructional use of refutational text structures were discussed.

Keywords: Refutation text; Conceptual change; Science learning; Learning from text

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1. Introduction

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,

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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" 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.

2. 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; 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 (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 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 to hinder comprehension

(Kim & Van Dusen, 1998; 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). 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 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, has been replicated with high-school students (Alvermann, Hynd, & Quian, 1995; Guzzetti, Williams, Skeels, & Wu, 1997) and college students (Alvermann & Hague, 1989; Chambers & Andre, 1995; 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, Paivio, & Pressley, 1994).

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 context where the text is used as an adjunct to the regular instruction that is normally provided.

In addition, previous research has shown refutation text to be more helpful with samples of high-school and college students (i.e., Alvermann et al., 1995; Chambers & Andre, 1995) than elementary-school students. On the basis of their meta-analytic study, Guzzetti et al. (1993) concluded that soft expository text that combines narrative with expository structures facilitates learning in the elementary grades to a greater degree than simple or refutational expository text. Although the results of Maria and MacGinitie (1987) with fifth- and sixth-graders appear to contradict this conclusion, it must be noted that the refutation texts they used were very short, single paragraphs each focusing on a specific preconception. Therefore, it remains unclear whether the use of longer refutation text targeting common science-related preconceptions can be extended to the elementary school level.

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, Cypriot sixth-grade 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.

3. 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, 2002; 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, 2002). 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 expected any effects with respect to learning or the target preconceptions to maintain over time.

4. Method

4.1. 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

Table 1
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.

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 ($p < .05$).

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 1. 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 hypothesis.

4.2. 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 to provide a review of the concepts covered during instruction and to draw students' attention to main ideas. It included three sections focusing on energy sources and forms, and energy transformation and storage. The first section, titled "What is Energy?," defined energy as the capacity for work and presented examples of human activities and changes of state requiring energy. The second section elaborated on the idea of energy consumption and transformation, and the third section described the various forms of energy and their characteristics. The order and the manner of concept presentation corresponded closely to the lesson that preceded the reading of the text and followed the guidelines of the Science Teachers' Manual (Kyprianou et al., 1997).

Refutation text. The expository text served as the basis for the refutation text which, in addition to providing a review of the concepts covered in the lesson, focused on two potential preconceptions, namely the lack of differentiation between energy and force and the conceptualization of energy as a substance. Therefore, its additional purpose was to prevent the formation and/or to facilitate the restructuring of these alternative conceptions.

The refutation text was 1039 words long and included four sections (Appendix A). The differences between the expository and the refutation text were (a) a discussion of the various meanings that the words energy and force take in everyday conversation as opposed to in scientific discourse in the first section; (b) an explicit contrast between energy and force in relation to energy consumption in the second section; and (c) the inclusion of a fourth section focusing on the distinction between energy and matter.

Energy test. 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, force, and matter. The test was administered to all students twice, one day after instruction and again one month later in order to assess maintenance of learning.

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 ten forced-choice items (Appendix B). Overall, four items focused on the distinction between energy and force (Questions 1A, 4A, 1B, and 9B, Appendix B) while three items focused on the immaterial nature of energy (Questions 3B, 4B, and 6B, Appendix B). For example, answers indicating that people have less energy—instead of strength or force—when they are tired (Question 1A) and that both children and adults will consume equal energy when lifting a box (Question 1B) would demonstrate an understanding of the distinction between energy and force. Similarly, negative answers to Questions 3B, 4B, and 6B (Appendix B) would demonstrate an understanding of the distinction between energy and matter. The rest of the items were designed to assess learning of the different forms of energy and their characteristics, which were the focus of the lesson.

Because we wanted to assess students' understanding instead of recall of text and lesson information, the majority of the items in the Energy Test were inferential, in the sense that their answers were not stated explicitly in any of the texts or presented in the lesson. At the other end, two items (Questions 2A and 5B, Appendix B) were literal. Two additional items (Questions 7B and 10B, Appendix B) were text-inferential, in the sense that reference to their answers had been made in the lesson but not in any of the texts. Finally, the answers to two items that focused on the distinction between energy and force (Questions 1A and 9B, Appendix B) were presented in the refutation text but not in the expository text or in the lesson. These items were counterbalanced with two inferential items targeting the same preconception (Questions 4A and 1B, Appendix B), and, therefore, we reasoned that any advantage resulting from their inclusion for the Refutation Text Group should be small and/or more likely to dissipate over time.

All 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. Scale analysis indicated that Question 4A (Appendix B) had the lowest item-total correlation ($r = .04$) and received answers unrelated to the energy/force distinction which was supposed to assess (e.g., "A very strong man has a lot of muscles"). Therefore, it was judged that it was not a sufficiently discriminating item and was dropped from all subsequent analyses. The reliability of the Energy Test with a total of 15 items was modest (KR-20 = .56) but acceptable given the purpose of the study (Nunnally, 1978). It must also be noted, 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 only performance on the Energy/Material items related to students' learning of the instructed concepts ($r = .29$, $p < .01$), and performance with respect to one preconception was relatively independent of performance with respect to the other ($r = .13$, $p > .05$).

4.3. Procedure

The study was conducted in four phases. In Phase 1, 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-min 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, and 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 min. 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 min 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.

Phase 4, the delayed testing phase, took place one month after instruction. The administration and the instructions were similar to those in Phase 3.

5. Results

Preliminary analyses indicated that Grade Point Average, Science Grade, and Reading Grade were all positively correlated with each other ($p < .01$). However, only Grade Point Average and Reading Grade were consistently and significantly related to all dependent variables ($p < .05$). 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—Energy/Force Score, Energy/Material Score, and Energy/Forms Score—were also normally distributed (skewness < 1). However, the variances of Delayed Energy/Force Score were not homogeneous (Cochran's $C = .56$, $p = .000$). Therefore, this variable was excluded from all parametric analyses.

The means of all dependent variables across Instruction Groups are shown in Table 2. 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, average total scores across groups were higher on the Delayed Energy Test than on the Immediate Energy Test (paired $t(204) = -4.83$, $p = .000$).

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 $T^2 = .53$, $F(2,200) = 53.15$, $p = .000$ and Hotelling's $T^2 = .25$, $F(4,398) = 12.61$, $p = .000$, respectively). 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 ($p < .01$). With respect to

Table 2
Mean proportion correct on immediate and delayed energy test across instruction groups

Variable	Instruction group		
	Refutation text	Expository text	Standard instruction
	Immediate energy test ($N = 212$)		
Energy/Force	.75 (.27)	.34 (.24)	.30 (.22)
Energy/Material	.74 (.30)	.60 (.33)	.68 (.33)
Energy/Forms	.47 (.19)	.43 (.17)	.43 (.19)
Energy total	.58 (.16)	.45 (.14)	.46 (.16)
	Delayed energy test ($N = 209$)		
Energy/Force	.73 (.30)	.34 (.18)	.28 (.19)
Energy/Material	.77 (.28)	.74 (.31)	.67 (.29)
Energy/Forms	.53 (.22)	.47 (.20)	.54 (.17)
Energy total	.62 (.18)	.50 (.15)	.52 (.15)

Note. Standard deviations are shown in parentheses.

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) $= .80$ and d (delayed) $= .74$—and the Standard Instruction Group—d (immediate) $= .74$ and d (delayed) $= .61$. 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, $d(\text{delayed}) = .12$ (see also Table 2).

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 $T^2 = .26$, $F(3, 206) = 18.03, p = .000$ and Hotelling's $T^2 = .83, F(6, 410) = 28.33, p = .000$, respectively). However, individual Analyses of Variance indicated that the main effect of Instruction Group was significant only with respect to the Energy/Force Score ($F(2, 209) = 75.56$, $p = .000$) and the Energy/Material Score ($F(2, 209) = 3.57$, $p = .029$). 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 $p < .05$, $d = 1.68$, and $d = 1.84$, respectively). In contrast, performance of the Expository Text Group was not significantly different from that of the Standard Instruction Group (Scheffe method, $p > .05$, $d = .16$). 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, $p < .05$, $d = .44$).

Response patterns to individual questions within each preconception category can be seen in Table 3. With respect to the Energy/Force Category, only one student in the Expository Text Group and one student in the Standard Instruction Group responded correctly to all items in the Category. In contrast, 34 students in the Refutation Text Group answered correctly all items in this Category. A similar pattern of responses emerged with respect to the Energy/Material Category, with the percentage of students in the Refutation Text Group who gave correct responses to individual questions or to all questions in the Category being higher than or, in one case, comparable to that of the percentage of students in the other Groups who similarly gave correct responses (Table 3).

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 $T^2 = .41$, $F(2, 202) = 41.72$, $p = .000$). However, a Kruskal–Wallis test showed that the differences between the Instruction Groups were still significant for the Energy/Force items, $\chi^2(207) = 84.15$, $p = .000$. Specifically, 79% 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 14% of the students in the Expository Text Group and 10% of the students in the Standard Instruction Group who similarly gave correct responses.

Table 3
Percentage of students responding correctly to individual questions and to all questions within each preconception category and across instruction groups

Questions	Instruction group		
	Refutation text ($n = 76$)	Expository text ($n = 73$)	Standard instruction ($n = 63$)
	Energy/Force category		
Question 1A	75	69	52
Question 1B	91	13	14
Question 9B	59	20	24
All questions	45	1	2
	Energy/Material category		
Question 3B	72	57	64
Question 4B	66	58	69
Question 6B	84	66	71
All questions	50	30	40

Note. Question content is shown in Appendix B.

6. 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). Instead, it was integrated within the classroom context and utilized as an adjunct to regular instruction. Moreover, and in contrast with previous findings (e.g., Guzzetti et al., 1993), refutational expository text was found effective with a sample of elementary-school students unfamiliar with science text and its structure (e.g., Cook & Mayer, 1988). All science instruction in the Cypriot elementary school (Grades 1–6) 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). Nevertheless, even a relatively brief exposure to the refutation text increased students' ability to distinguish concepts that previous research has shown to be commonly confused with each other (e.g., Ioannides & Vosniadou, 2002; 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 the acquisition of knowledge incompatible with existing beliefs.

The present study was not specifically designed to provide answers as to why refutation text is more conducive to the acquisition of counterintuitive concepts. An examination, however, of the refutation text used in this study may provide the basis for potential explanations. With respect to the energy/force distinction, the inclusion of text questions that follow from considering common everyday activities and the language used to account for them could have promoted student involvement and, therefore, deeper processing (e.g., Chinn & Brewer, 1993). However, students were not directed to answer text questions on their own and to justify their answers. On the other hand, explicit reference to a variety of answers representing different explanations that originate from different meanings might have resulted in the recognition of one of them as the students' own, and, therefore, the activation of relevant knowledge structures. Moreover, the subsequent contrast between common and scientific explanations may have served to focus students' attention on the differences between their conceptions and the scientific conceptions and to promote cognitive conflict (Guzzetti et al., 1997). Conversely, considering that this was our students' first formal encounter with the concept of energy, the extended discussion of the different answers and explanations in relation to common, everyday activities may have also served to further elaborate an unfamiliar difficult concept (Kim & Van Dusen, 1998). Finally, the explicit positioning of energy and force within the familiar structure of a causal chain may have played the role of an anchor contributing to an initial, albeit incomplete, representation of their difference as well as their relationship (see also Linderholm et al., 2000). Therefore, we consider it more likely deeper processing to have resulted from references to and comparisons between ideas and the explanatory frameworks that give rise to them.

It can be argued, however, that the refutation text used in this study has weaknesses both with respect to the actual scientific conception of energy as well as to its potential for inducing conceptual change. One such weakness concerned the apparently insufficient elaboration of energy as the capacity for work. Specifically, the notion that who- or whatever has greater capacity for work has also more energy was not emphasized in the refutation text, and that may have contributed to the failure of Question 4A (Appendix B) whose initial purpose was to assess understanding of this issue. An additional potential weakness of the refutation text that relates to the treatment of the energy/matter distinction was the use of materialistic language. According to Chi and her colleagues (Chi, Slotta, & de Leeuw, 1994; Reiner et al., 2000), novices have a tendency to rely on more familiar substance-based conceptions when trying to understand a new science concept. In that case, understanding energy as an abstract concept instead of as a material entity would require an ontological shift on the part of the students (Chi et al., 1994). The purpose of the last section on the refutation text was to help initiate and facilitate such a reassignment of the concept of energy to the category of concepts representing processes. This purpose, however, may have been compromised by the predominantly materialistic language utilized in the rest of the text.

However, the construction of the refutation text, as well as that of the expository text which served as its basis, had to conform to a number of constraints. First, the text had to be consistent with the main lesson to which it served as an adjunct. Therefore, any changes with respect to the content—other than those necessary to facilitate restructuring of targeted preconceptions—or to the language used would have defeated the purpose and the function of the refutation text in this study. If that were the case, any performance differences between the groups—although still attributable to instructional intervention differences—would have no implications concerning the extent to which refutation text can complement and reinforce the instruction that is normally provided. Second, the refutation text also had to comply with and address the knowledge needs of the students who were expected to learn from it. In discussing the educational implications of their research, Reiner et al. (2000) concede that to completely avoid materialistic language may not be effective as it can prevent students from accessing whatever knowledge they have in order to make sense of new concepts. We believe that, given our students' novice status with respect to the target concept, the use of completely non-materialistic language to define and explain energy—if at all possible—would have rendered the text incomprehensible to our students and, therefore, either ineffective or detrimental to their actual understanding of the concept.

Overall, it is noteworthy that the refutation text was most successful in promoting the understanding of issues that were its explicit focus. The elaboration on the differences between energy and force in relation to their use in everyday conversation resulted in substantially higher performance on all three test items that targeted this distinction. If we consider that both energy and force represent abstract physics concepts that are difficult to distinguish from each other (Ioannides & Vosniadou, 2002), then, it can be argued, that even a rudimentary understanding of them as different and yet related opens the way for subsequent learning of their applications and implications in science. On the other hand, failure to keep these concepts apart in the mental representation will more than likely frustrate future efforts to understand other aspects and concepts related to one or both of them.

With respect to the energy/matter distinction, the performance of students who read the refutation text was also higher than that of students who read the simple expository text or students who did not read any text. However, group differences were not as pronounced as those in relation to the energy/force distinction. It is interesting to note that this finding appears to reflect the amount of elaboration included in the refutation text in relation to this distinction and in comparison to the energy/force distinction. In fact, only a single paragraph was devoted to the non-material nature of energy, and students were simply told that energy is not a material entity that can be perceived through the senses. Therefore, the findings concerning the two preconceptions taken together seem to suggest that the extent to which refutation text will promote the acquisition and the understanding of a concept depends on the extent and the depth of the elaboration it provides with respect to that concept.

The findings of the present study may appear to be inconsistent with those of Mayer, Bove, Bryman, Mars, and Tapangco (1996), who found that a summary was more effective than a longer 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 passage employed by Mayer et al. (1996) presented factual information and explanations and, therefore, resembled our simple expository text which was also found to be relative ineffective. We 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. As Guzzetti et al. (1997) have shown, any cognitive conflict induced by refutation text may not always be sufficient for conceptual change, rendering supportive activity necessary. 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. 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 target 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. In addition, the one-month period that elapsed between instruction and the delayed test may have been too short (e.g., Chambers & Andre, 1995; Hynd et al., 1997), and, therefore, the possibility of carry-over effects cannot be precluded.

One could also argue that the extent to which the refutation text actually induced conceptual change is questionable. Students' preconceptions about energy were not assessed by means of a pretest. We reasoned, however, that the responses of students who did not read any text and those who read the simple expository would provide an overall indication of the extent to which the target preconceptions were held as well as the basis for treatment comparisons. In fact, our findings showed that it was only with respect to the hypothesized preconceptions that the positive influence of the refutation text became apparent. Otherwise, the refutation text contributed almost nothing to the acquisition of the general knowledge about energy forms that was the primary focus of the lesson.

Nevertheless, it would be premature to conclude that the students in this study restructured their preconceptions as a result of reading the refutation text. The test that was used to assess learning was relatively short, and the students were not required to justify or elaborate on their answers. Although the majority of the test questions did not assess simple recall of text or lesson information, they were far from representing completely inferential or generative items of the type utilized by Vosniadou and Brewer (1992). Answering them correctly required thinking about and going beyond the information given but not using them to solve novel problems. Therefore, a longer and/or more open-ended test that required students to apply newly-acquired concepts extensively and to use them in problem solving might have been more sensitive to finer gradations of understanding as well as to overall depth of understanding. In addition, the instructional intervention in this study was carried out by the regular classroom teachers. Although every effort was made to ensure uniformity of teaching where necessary, the possibility of group differences due to teaching style and ability cannot be completely ruled out. These two limitations prohibit any strong claims concerning the extent to which actual restructuring took place as a result of reading. What our findings do indicate, however, is that students who read the refutation text appeared to have understood, at a basic level, what concepts to keep apart as distinct from each other in their mental representations. That understanding, in turn, may serve as the stepping stone for conceptual change.

7. Conclusion

Refutation text was found to facilitate the acquisition of conceptual distinctions even when it was used in a regular classroom setting and as an adjunct to the standard instruction provided. Given the limitations of this study and, particularly, those related to the assessment instrument, the present findings can be taken only as preliminary. Further research is needed to establish the depth of understanding and the extent of conceptual restructuring that can be achieved from exposure to refutational text structures. However, we consider the findings of this study, as well as research focusing on the effects of refutation text in general, as 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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Appendix A. Energy

A.1. 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.[1] In everyday conversation, when we say that people have force[2] 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

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[1] Parts common to both the expository and the refutation text appear in italics. The expository text, however, included additional material that mainly represented extensions and elaborations of the parts shown here.

[2] The word "force" is used, sometimes, inappropriately 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.

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.[3] So, if both the adult and the child lift it, then they would both have exerted equal force.

A.2. Energy is consumed and replenished[4]

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.

A.3. 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. The energy 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 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

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

[4] 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.

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.

A.4. 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 B. Energy test

B.1. Part A

1. Why is it that sometimes, when we are tired, we cannot run as fast as other times?
2. In a closed electric circuit, what form(s) of energy does the battery have?
3. In a closed electric circuit, what form(s) of energy does the battery produce?
4. A very strong man has a lot of ___________.
5. A loaf of bread has just been taken out of the oven. What form(s) of energy does it have?
6. A cat has stolen the fish that was just taken out of the oven and runs to escape. What form(s) of energy does the fish have?

B.2. Part B

1. When a child and an adult lift a heavy box they consume
   (a) equal amounts of energy
   (b) different amounts of energy
2. A fireplace produces
   (a) more
   (b) less
   energy than a lamp.
3. If we use a very strong microscope, can we see the energy in gasoline?
   (a) yes
   (b) no

4. Scientists say that different foods have different amounts of energy. Do they know that from measuring energy with special weight scales?
   (a) yes
   (b) no
5. Chemical and elastic energy can be stored.
   (a) yes
   (b) no
6. Can we take out the energy in 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, of the same model and with the same number of passengers, travel on the highway. The speed of Car A is 70 km/hour, while the speed of Car B is 100 km/hour.
   (a) Car A has more energy
   (b) Car B has more energy
9. When we eat, do we replenish our lost force(strength)?
   (a) yes
   (b) no
10. Is chemical energy emitted?
    (a) yes
    (b) no

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