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On Warm Conceptual Change: The Interplay of Text, Epistemological Beliefs, and Topic Interest

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The aim of this study was to go further than considering only cognitive factors to extend the understanding of the complex, dynamic underlying knowledge revision processes. Fifth graders were assigned to 2 reading conditions. Participants in 1 condition read a refutational text about light, whereas participants in the other read a traditional text. Within each reading condition, students had more or less advanced beliefs about scientific knowledge (complex and evolving vs. simple and certain), as well as high or low topic interest. Overall findings from pretest to immediate and delayed posttests showed that knowledge revision was affected by several interactions among the variables examined. Students who attained the highest scores at both the immediate and delayed posttests were those who had read the refutational text and had high topic interest, as well as more advanced beliefs about scientific knowledge. In particular, the refutational text was more powerful in prompting a restructuring of alternative conceptions about 2 of the 3 light phenomena examined. In addition, students preferred the innovative text to the traditional textbook text.

Keywords: conceptual change, refutational text, epistemological beliefs, interest

In their classic article, Pintrich, Marx, and Boyle (1993) called for *hot conceptual change,* that is, to go further than considering only cognitive factors and to also take into account the affective, motivational, and social/contextual aspects that may affect knowledge revision. As described by Sinatra (2005), this article inspired a *warming trend* in theory and research on conceptual change. New models and empirical studies began emphasizing motivation as crucial to knowledge restructuring. Our study examined two learner factors considered by Pintrich and associates (Pintrich, 1999; Pintrich, Marx, & Boyle, 1993) as possible motivational resources for conceptual change: epistemological beliefs and interest. The study also examined an instructional factor, the type of text to be learned to integrate new knowledge into existing conceptual structures. Our study therefore focused on the interplay between instructional and learner variables to extend the understanding of the complex dynamics underlying the process of conceptual change. The investigation of this interplay is in line with most recent research in this field, which highlights the intricacy of the change process and the delicate interactions of multiple factors that shape that process (Alexander & Sinatra, 2007; Murphy & Mason, 2006; Sinatra & Mason, in press). In previous research, these three variables have been examined separately (e.g., Hynd, 2003; Qian & Alvermann, 2000; Qian & Pan, 2002; Venville & Treagust, 1998) or in pairs, for example, refutational text and epistemological beliefs (Mason & Gava, 2007) or epistemological beliefs and interest (Mason & Boscolo, 2004).

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Refutational Text

Most learning required in the school context occurs through successful text reading. Text is still the main medium for acquiring disciplinary knowledge. It is widely accepted that the text comprehension process implies constructing a mental representation of the text or situation model based on integrating information found in the text with the reader's prior knowledge (Chan, Burtis, Scardamalia, & Bereiter, 1992; Goldman & Bisanz, 2002; Kintsch, 1986). This integration often requires readers to restructure their preconceptions if they are incompatible with the new knowledge to be learned. The role of text in promoting conceptual change may therefore be crucial. Science texts are expository texts that provide information about phenomena usually by presenting a series of facts. There is evidence that the structure of standard science texts may induce only superficial processing and may fail to sustain meaningful learning, especially when the reader has alternative conceptions about the topic (e.g., Chambliss, 2002). In the study reported here, we examined the role of the refutational text, which has been found to be effective in science learning because of its structure. A refutational text is a text that acknowledges students' alternative conceptions about a topic, directly refutes them, and introduces scientific conceptions as viable alternatives (Alvermann & Hague, 1989; Hynd, McWhorter, Phares, & Suttles, 1994; Hynd, Qian, Ridgeway, & Pickle, 1991).

The first studies showing the power of a refutational text structure were carried out in the 1980s. For example, Maria and MacGinitie (1987) revealed that fifth and sixth graders more easily abandoned their misconceptions about common topics when they read a refutational text than when they read an expository one that simply presented the new information. Since then, the effectiveness of refutational texts in knowledge-restructuring processes has been revealed in several studies (e.g., Guzzetti, Snyder, Glass, & Gamas, 1993; Guzzetti, Williams, Skeels, & Wu, 1997; Qian & Pan, 2002). More specifically, the superiority of a refutational text, compared with a traditional one, has been documented in the learning of physics (Hynd, 1998; Wang & Andre, 1991) and biology concepts (Mikkilä-Erdmann, 2002) in students of elementary school (Diakidoy, Kendeou, & Ioannides, 2003), middle school (Mason & Gava, 2007), high school, and college (Alvermann & Hynd, 1989; Chambers & Andre, 1997), as well as in the change of preservice teachers' beliefs about mathematics teaching and learning (Gregoire Gill, Ashton, & Algina, 2004). Through interviews, it also emerged that students prefer refutational texts over other types of science texts about the same topic (e.g., Guzzetti, Hynd, Skeels, & Williams, 1995; Hynd, 2003).

Why are refutational texts powerful? According to Hynd (2003), three explanations can account for the benefits of refutational texts. The first refers to the four conditions for conceptual change, highlighted in the well-known article by Posner, Strike, Hewson, and Gertzog (1982). In other words, refutational texts elicit dissatisfaction with the reader's current conceptions, explain the scientific concept clearly and in depth, make it plausible through believable examples, and finally show the usefulness of the new concept. The second explanation for the power of refutational texts refers to the necessary characteristics of any anomalous data that increase the likelihood that they be accepted as valid. That is, to be accepted, data must be credible, unambiguous, and in multiple forms (Chinn & Brewer, 1993, 1998). The third explanation, grounded in social psychology literature, refers to readers' central, and not peripheral, text information processing, activated by refutational texts. A fourth explanation can be added, regarding the possibility that refutational texts enhance situational interest. As discussed later, this type of interest is triggered by specific text characteristics, for example, concreteness and ease of comprehension (e.g., Schraw, Bruning, & Svoboda, 1995), and may enhance learning.

Epistemological Beliefs

When confronted with new knowledge to be learned, students do not just activate their preexisting knowledge about the topic but also activate their beliefs about knowledge itself. Beliefs about knowledge and knowing, namely epistemological beliefs, are individuals' representations about the nature, organization, and source of knowledge, its truth value, and the justification criteria of assertions (Hofer & Pintrich, 1997, 2002). In the work of scholars interested in developmental aspects, epistemological thinking has been considered a cognitive structure comprising coherent and integrated representations, which characterizes a level or stage of cognitive development. A shared developmental sequence can be identified in their models (e.g., King & Kitchener, 1994; Kuhn, 2000; Kuhn, Cheney, & Weinstock, 2000). Substantially, the shift indicated is from belief in knowledge as absolute, simple, certain, and transmitted by authorities, to belief in knowledge as relative, idiosyncratic, and uncertain, to belief in knowledge as complex, evolving, rationally evaluated, and derived from reason.

In the work of scholars interested in the relationship between epistemological beliefs and learning processes, the construct of epistemological beliefs has been conceived as multidimensional. Agreement about four epistemological dimensions can be identified in the literature (e.g., Hofer, 2000, 2004; Schommer, 1990, 1994; Schommer-Aikins, 2002; Wood & Kardash, 2002). Two dimensions regard the nature of knowledge. The first concerns beliefs about the simplicity versus the complexity of knowledge: the degree to which knowledge is conceived as compartmentalized or interrelated, ranging from knowledge as made up of discrete and simple facts to knowledge as complex and interrelated concepts. The second dimension concerns beliefs about the certainty versus the complexity of knowledge: the degree to which knowledge is conceived as stable or changing, ranging from absolute to tentative and evolving knowledge. Two belief dimensions regard the nature of knowing. The first concerns the source of knowledge: the relationship between knower and known, ranging from the belief that knowledge resides outside the self and is transmitted to the belief that knowledge is constructed by the self. The second dimension concerns the justification of knowledge: what makes a sufficient knowledge claim, ranging from the belief in observation or authority as a source to the belief in the use of rules of inquiry and evaluation of expertise. According to some scholars (e.g., Schommer, 1990), these four epistemological dimensions may be independent, and an individual may have more sophisticated beliefs in one of them and less sophisticated beliefs in another. According to some other scholars (e.g., Hofer, 2000), beliefs about knowledge and knowing are not a set of independent ideas, but rather are a coherent integration of compatible perspectives, that is, theories, whose core is comprised of the four dimensions. Although divergences exist in their conceptualization of epistemological beliefs (see also Hammer & Elby, 2002), overall it can be said that scholars substantially agree on the essential steps in the development of representations about knowledge and knowing.

In agreement with Bendixen (2002), who examined the perception, description, and solution of epistemic doubt in undergraduate students, it should also be pointed out that epistemological beliefs are not *cold cognition*. The affective nature of deeply held beliefs is an important aspect to be taken into consideration. The recognition of uncertainty and complexity of knowledge can be worrisome for students. Affective consequences (i.e., feelings of fear, confusion, or anxiety) may also derive from abandoning the security of absolutistic stances (Hofer, 2005).

A number of empirical studies have been carried out concerning the relationship between epistemological beliefs and conceptual change learning. To our knowledge, almost all studies are based on the conceptualization of personal epistemology as a multidimensional construct, which has been measured through questionnaires made up of items to be rated on a Likert-type scale. More specifically, original or reduced versions of Schommer's (1990) Epistemological Questionnaire have been used. It should be pointed out, however, that in many cases, the focus has been on two of the four dimensions underlying this instrument, that is, beliefs in the simplicity versus the complexity of knowledge and beliefs in the certainty versus the uncertainty of knowledge. Thus, the label *epistemological beliefs* may refer only to beliefs about the structure (simplicity vs. complexity) and stability (certain vs. evolving) of knowledge. In reviewing previous studies, we specify which dimensions of beliefs are examined.

Qian and Alvermann (1995) found that after reading a text on Newtonian theory, high school students who believed more in the simplicity and certainty of knowledge were less likely to abandon naïve conceptions of motion. In contrast, students who believed more in the complexity and instability of knowledge produced greater change in their conceptual structures. Windschitl and Andre (1998) documented that college students with beliefs in knowledge as complex, evolving, and gradually learned changed their initial conceptions about the cardiovascular system more in the constructivist than in the traditional learning environment. Sinatra and colleagues (Sinatra, Southerland, McConaughy, & Demastes, 2003; Southerland & Sinatra, 2003) investigated not only epistemological beliefs but also cognitive dispositions—such as the disposition to engage in effortful, open-minded thinking and not to identify too strongly with one's beliefs—in relation to the acceptance of human evolution. College students who believed more in complex and uncertain knowledge and had a greater disposition toward critical and open-minded thinking were more likely to accept human evolution than students with less advanced epistemological beliefs who were less disposed toward critical and flexible thinking. Kardash and Scholes (1996) also found that the more college students were disposed to cognitive involvement, the more they wrote paragraphs taking into account the inconclusive nature of controversial evidence presented in the dual-positional text that they read. In addition, the more they believed in uncertain knowledge, the less radical were their initial beliefs about the controversy. In line with Chinn and associates' (Chinn & Brewer, 1993; Chinn & Malhotra, 2002) analysis of the factors that facilitate or constrain theory change, Mason (2000) documented that beliefs about the certainty of knowledge were related to the acceptance of anomalous data, as well as to theory change about a controversial scientific topic. Middle school students who believed in the changing nature of knowledge were more likely to recognize the validity of evidence conflicting with their prior conceptions and, consequently, to change them.

More recently, Nussbaum, Sinatra, and Poliquin (2005) found that college students with evaluativist positions about the physical world—those who believed that different knowledge claims are legitimate but can be rationally compared and evaluated to judge which is more sustainable—showed a greater decline in misconceptions about falling objects than students with absolutist positions. Stathopoulou and Vosniadou (in press) also indicated that 10th graders' physics-related beliefs about the structure, stability, source, and attainability of knowledge were necessary, although insufficient, for a conceptual understanding of physics.

The relationship between epistemological beliefs and text (refutational vs. traditional) reading in conceptual change processes has also been studied (Mason & Gava, 2007). Eighth graders who read a refutational text and believed more in complex and uncertain knowledge changed their misconceptions about biological evolution more than those who read a traditional text.

Why do more sophisticated epistemological beliefs act as a resource whereas less sophisticated beliefs act as a constraint in conceptual change? An account based on the notion of intentionality can be proposed (Sinatra & Pintrich, 2003a). As posited by Sinatra and Pintrich (2003b), a key to intentionality in knowledge revision processes is that "students must have a deliberate *goal orientation* . . . to learn and understand the material" (p. 5). By appealing to this notion, Mason (2003) proposed that beliefs about knowledge may or may not guide students toward the goal of learning through knowledge revision. In this case, intentionality requires that students recognize that what they already know does not match a new conception or that they perceive the potential of new information. Only beliefs in complex, hypothetical, and evolving knowledge are conducive to that recognition. Once they have recognized that, students must invest their effort in solving problems concerning the current state of their own understanding in order to intentionally produce changes in knowledge (Mason, in press). Systematic or deep processing of the content (Kardash & Howell, 2000) seems to mediate the role of epistemological beliefs in intentional conceptual change. Gregoire Gill, Ashton, and Algina (2004) have documented that preservice teachers who held beliefs in knowledge as simple and certain were less likely to engage in deep thinking about the content of a text and, in turn, were less likely to change their beliefs about mathematics teaching and learning. Epistemological beliefs may also have a direct effect because the conviction that knowledge is simple and certain may lead a student to focus only on items of factual knowledge (Stathopoulou & Vosniadou, in press).

Topic Interest

We examined a third variable, interest, that may play a role in conceptual change learning. Neglected for decades, this motivational variable has been reconsidered since the mid-1980s (Hidi & Baird, 1986). Conceptualized in terms of both a psychological state and an individual predisposition, interest has been investigated for its influence on cognitive and affective functioning (Renninger, 1990, 2000; Renninger, Ewen, & Lasher, 2002; Renninger & Wozniak, 1985; Schiefele, 1991, 1996). Studies on the relationship between interest and learning have mainly been conducted in the light of the useful distinction between individual and situational interest (Alexander, 1997, 1998; Hidi, 2001; Renninger, 1992; Renninger, Hidi, & Krapp, 1992; Tobias, 1994). Individual interest is distinct from other related motivational constructs and is a relatively stable evaluative orientation toward certain classes of objects, ideas, or events, which is reflected in a relatively enduring predisposition to re-engage with them over time. Situational interest is generated by certain conditions and/or environmental stimuli, such as novelty and intensity. Typically, textual features can elicit a form of interest, called situational interest, that refers to short-term involvement with a class of objects (Renninger, 2000). It has been maintained, however, that situational interest may evolve into individual interest (Hidi & Anderson, 1992), as well as that well-developed individual interest needs to be sustained and challenged (Renninger & Hidi, 2002).

Of special note is research on the development and deepening of interest in subject matter (e.g., Lipstein & Renninger, 2006). A four-phase model has recently been proposed, which relates the constructs of individual interest and situational interest (Hidi & Renninger, 2006). This model includes the following: triggered situational interest, maintained situational interest, emerging individual interest, and well-developed individual interest. Each phase includes both affective and cognitive factors, that is, a certain amount of affect, knowledge, and value. It has been documented that continued (individual) interest in a discipline is related to types of achievement goals. College students' mastery goals predicted their interest in an introductory psychology course (Harackiewicz, Barron, Tauer, Carter, & Elliot, 2000).

In the current study, we examined topic interest, a motivational construct used in both the individual and situational literatures "to refer to the likelihood of attending to particular subject content . . . or positive feelings for content" (Renninger, 2000, p. 376). We examined topic interest, which is distinct from both individual and situational interest, for two main reasons. First, it is particularly relevant to educators (Ainley, Hidi, & Berndorff, 2002), because this type of interest is most likely evoked when students are introduced to topics in school contexts that they are asked to learn about. Second, for a study focused on changing conceptions about specific scientific phenomena, it was more appropriate to take into account students' degree of interest in the specific topic to be learned about, in addition to their prior knowledge of it.

It is worth noting that topic interest can be considered, to some extent, both individual and situational (Renninger, 2000). Indeed, topic interest can be an expression of individual interest in a specific subject matter, for example, science. At the same time, it can be an expression of situational interest in that it is stimulated by a specific content. Therefore, most topics have both individual and situational sources that contribute to the measured topic interest (Ainley, Hidi, & Berndorff, 2002), especially in young learners, where the former may not be well developed. In the current study, we do conceptually acknowledge that individual interest in science, as well as interest elicited by words or sentences presenting the topic of light, would contribute to the measured topic interest. Nevertheless, topic interest can be conceived as a motivational variable distinct from both individual and situational interests. In addition, although it relates to situational aspects, topic interest can be included as a personal variable, as has been done in most previous investigations. In the current study, it has been considered as a learner variable together with selected relevant dimensions of epistemological beliefs.

Two aspects of topic interest have been distinguished (Krapp, 1999; Schiefele, 1996) and have been taken into account in the study reported here: feeling-related and value-related valences. Feeling-related valences refer to the feelings, for instance, stimulation and involvement, associated with a topic. Value-related valences refer to the attribution of personal significance to a topic. With regard to Hidi and Renninger's (2006) model of interest development, it can be said that topic interest may be an expression of each of the four phases, depending on the contribution of its sources and the degree of cumulative and progressive development. If situational components prevail, one of the two earlier phases is involved, especially in terms of affect or liking and focused attention. If the individual components prevail, one of the later phases is involved, implying not only positive feelings but also stored knowledge and value and repeated engagement.

Although not focused on the change in knowledge, several studies have indicated that topic interest positively influences learning from text. Alexander, Kulikowich, and Schulze (1994) found that college students' topic knowledge and interest significantly predicted comprehension of a technical text on physics. Schiefele (1996) showed that senior high school students with high interest in the topics of prehistoric people and television developed a deeper text comprehension than readers with low interest, regardless of level of prior knowledge. Similarly, in a study by Schiefele and Krapp (1996), topic interest in communication significantly affected recall of idea units, elaborations, and main ideas regardless of preexisting knowledge. In Alexander and Murphy's (1998) study, strong interest in concepts such as memory, problem solving, and learned helplessness, as well as willingness to pursue understanding, differentiated highly successful from less successful college students. Boscolo and Mason (2003) found that when high school students' topic interest in global warming was high, it could help their understanding of a text at the superficial level, and also at deeper levels, if associated with high topic knowledge. Ainley, Hidi, and Berndorff (2002) examined whether and how eighth and ninth graders' individual and situational interest contributed to their interest in and learning about different topics, such as body image and X rays. They combined both self-reported measures and online, dynamic measures of affective and cognitive reactions to the reading of science and popular culture texts, through the computer program Between the Lines. Topic interest was the outcome of both individual and situational interest factors, which operated in combination or separately. In addition, topic interest was related to affective responses. These were related to persistence that, in turn, was related to learning.

Very few studies have examined the relationship between interest, in either form, and conceptual change, and those that have have revealed that interest may not always be beneficial to conceptual change. In a study of high school students' understanding of genetics, Venville and Treagust (1998) reported some contradictory data. Students interested in the topic produced either high or very low levels of conceptual change. However, students' high interest was in human heredity and not in the microscopic aspects of genetics to be learned. Murphy and Alexander (2004) found that college students with high topic interest were less likely to alter their beliefs. The high correlation between interest and prior knowledge, and the fact that high knowledge often means more resistance to change, could be the cause of the lack of change. As pointed out by Dole and Sinatra (1998), interest could make knowledge revision more difficult if associated with high knowledge. In light of differences in the phases of interest development (Hidi & Renninger, 2006), it is more likely that a well-developed interest acts as a barrier to conceptual change when related to highly developed alternative conceptions.

The positive effect of interest in conceptual change processes has been documented by Andre and Windschitl (2003). They found that college students' interest in learning about electricity affected conceptual change indirectly, through experience that correlated with it, and also directly, independently of its influence on experience. The relationship between topic interest and epistemological understanding has also been examined in high school students' interpretation of a controversy (Mason & Boscolo, 2004). No significant interaction emerged between the two examined variables, although both played a role as single factors.

Why does a high degree of topic interest act as a resource, whereas a low degree may act as a constraint in conceptual change learning? The beneficial effect on interest can be explained by reference to an energizing role in cognitive processing, because it stimulates attentional arousal, positive emotional reactions, effort, and willingness to persist in the task, as documented empirically (e.g., Ainley, Hidi, & Berndorff, 2002) and underlined theoretically (e.g., Alexander, 1998; Hidi, 1990; Renninger, 2000). High interest therefore sustains deep cognitive processing, which is beneficial to knowledge revision and requires engagement in deep thinking about the content to be learned.

Research Questions and Hypotheses

To extend current research on conceptual change, we focused on the complex dynamics underlying the process. The aim of this study was to investigate how the text type to be learned and students' epistemological beliefs and topic interest affect revision of their conceptions about a topic. All three variables—each of which can contribute to stimulate and sustain active involvement and deep processing—and their possible relationships in knowledge-restructuring processes were the focus of the study. The variable of students' reading comprehension ability was also considered as a covariate in the statistical analyses. Because the students made up regular heterogeneous classes, their reading ability varied. We chose the topic of light, first because it is a topic central to the Italian science curriculum for the fifth grade, and it had not already been dealt with in the classroom. Second, the students had very low prior scientific knowledge of the topic, and this allowed a better examination of how the chosen variables contributed to new learning.

In particular, the purpose of the study was to examine the following questions:

1. Was students' text retention at the immediate and delayed posttests affected by text type, beliefs about the certainty and development of scientific knowledge, topic interest, and/or their interactions?

2. Was students' overall conceptual change, as reflected by changes in their explanations about light phenomena from pretest to immediate and delayed tests, affected by text type, epistemological beliefs, topic interest, and/or their interactions? In addition, did these factors affect, to the same extent, knowledge restructuring of each of three phenomena about light?

3. Did students prefer a refutational text to a traditional textbook text?

For the first research question, we hypothesized that no significant differences would emerge between participants for the retention of factual information in relation to epistemological beliefs, topic interest, and text type. Because the refutational and traditional texts did not differ in terms of information, participants would retain the same content in the two reading conditions. In addition, as emerged in a previous study (Mason & Gava, 2007), epistemological beliefs would not affect a shallow level of text understanding, which does not require the revision of prior knowledge. Finally, topic interest also would not differentiate text retention because it does not imply deep cognitive processing, which is sustained by the motivational variable.

For the second research question, we hypothesized overall that text type, beliefs about the nature and stability of scientific knowledge, and topic interest would make a difference at the level of deeper text understanding immediately after reading the text and at a delayed posttest. This is the situation model level in Kintsch's (1998) terms; that is, the reader's prior knowledge is integrated with information from the text, which reflects students' conceptual change. Only when the text information becomes part of the reader's knowledge as it integrates with it, can this information be used in new situations. We hypothesized that the text type would affect students' conceptual change overall. By directly stating and challenging students' alternative conceptions, a refutational text, more than a traditional text, would create or refine students' metaconceptual awareness about their own representations and scientific ones, an essential condition for conceptual change (Vosniadou, 2003; Wiser & Amin, 2001). This would increase the likelihood that the former are perceived as limited and the latter as more powerful. We also hypothesized that students with more advanced epistemological beliefs (scientific knowledge as uncertain and changing) would change their alternative conceptions more than those with less advanced epistemological beliefs (scientific knowledge as certain and stable) and that these changes would be persistent.[1] Participants with more advanced epistemological beliefs would be helped in perceiving knowledge problems in their conceptual structures and working toward solving them. Finally, we hypothesized that topic interest would affect knowledge revision overall because this motivational variable would stimulate attentional arousal and deep processing.

For the second research question, we also expected that an interaction among the three variables would emerge. Refutational text reading, more advanced beliefs about the nature of scientific knowledge, and higher topic interest would be a powerful combination of the instructional and personal variables. On the contrary, traditional text reading, less advanced epistemological beliefs, and low interest would lead to a lower performance.

On the basis of the literature, for the third research question we hypothesized that students would prefer a refutational text, which states and challenges their conceptions, to a traditional text, because it is perceived as easier and more helpful in understanding scientific concepts (Guzzetti et al., 1995).

Method

Participants

Initially, the participants involved were 120 fifth graders attending five classes in three public elementary schools in a province of north eastern Italy. All were Caucasian native speakers of Italian and shared a homogeneous middle class social background. Eight of these students were found to have reading difficulties (described later) on administration of a standardized reading comprehension text. In agreement with their teachers, they took part in the study, but their production was not considered in statistical analyses. In addition, a further 6 students were not present at either the pretest or the immediate posttest. There were therefore 106 participants

[1] In the epistemological beliefs literature, terms such as *naïve* and *sophisticated* or *less advanced* and *more advanced* are used. We retain them for reasons of clarity and not to attribute any unfortunate connotation to the terms. In accordance with Schommer-Aikins (2002), we think that when an individual holds sophisticated beliefs, it means that he or she believes mostly in complex and tentative knowledge. However, at the same time, the individual may believe that there is knowledge that is stable and/or isolated. What differentiates an advanced epistemological thinker from a less advanced one is that the belief in certain and simple knowledge is predominant in the latter and is the exception in the former.

who provided data for both the pretest and the immediate posttest. Of these 106 students, 12 were absent on the day of the delayed posttest. Therefore, 94 participants completed the pretest, the immediate posttest, and the delayed posttest (48 girls and 46 boys).

Each class was randomly assigned to one of two reading conditions: a refutational text about light ($n = 51$; 24 girls and 27 boys, including pretest and immediate and delayed posttests) and a traditional text about the same topic ($n = 43$; 24 girls and 19 boys, including pretest and immediate and delayed posttests).

Prereading Materials and Tasks

Epistemological beliefs. All but one (Stathopoulou & Vosniadou, in press) of the studies reported in this article used a questionnaire intended to measure general beliefs about knowledge. In this study, we used a more appropriate, science-specific questionnaire, which was an abbreviated version of Conley, Pintrich, Vekiri, and Harrison's (2004) instrument for measuring epistemological beliefs about science in elementary school students. In this way, we tried to overcome the measurement difficulties underlying the use of abstract and domain-general statements. Conley et al.'s (2004) instrument comprises four scales that focus on the core dimensions of epistemological beliefs. Our reduced version comprised 12 items in two scales, one measuring certainty (i.e., "Scientific knowledge is always true") and one measuring development of knowledge (i.e., "Some ideas in science today are different from what scientists used to think"). We used these scales only as they were the most pertinent to the focus of the study (see the Appendix). It should be pointed out that these scales substantially overlap the scales measuring simplicity and certainty in the work of Hofer (2000; Hofer & Pintrich, 1997). Items were rated on a 5-point Likert-type scale (1 = *strongly disagree*, 5 = *strongly agree*). The scale measuring certainty was reversed so that for each item of the two scales, higher scores reflected more sophisticated beliefs.

The alpha reliability coefficient of this reduced version of the instrument was .73. The total score in epistemological beliefs was dichotomized on the basis of the median and was used to create two mutually exclusive groups. One comprised students with more advanced beliefs about the nature of scientific knowledge ($n = 40$; 22 in the experimental condition and 18 in the control condition), and the other comprised students with less advanced beliefs ($n = 54$; 29 in the experimental condition and 25 in the control condition).

Topic interest. The authors devised a 10-item interest questionnaire, with items to be rated on a 5-point scale (1 = *not at all,* 5 = *much*), to measure participants' level of interest in the topic of light—the topic of the text to be read (see the Appendix). As in previous studies focused on a single topic to be learned (e.g., Boscolo & Mason, 2003; Mason & Boscolo, 2004; Schiefele, 1996; Schiefele & Krapp, 1996), a questionnaire given before text reading was considered to be a more appropriate way to measure students' evaluative orientation toward content than the simple rating of a title on a content area (e.g., Flowerday, Schraw, & Stevens, 2004). The items were formulated by taking into account the two aspects of interest that have been distinguished (Krapp, 1999; Schiefele, 1996): feeling-related and value-related valences. An example of a feeling-related item is "I would be excited about studying light in science classes." An examples of a value-related item is "Knowing how we can see the different colors of objects is not important to me." The knowledge component, which has been included in the conceptualization of interest offered by Renninger and other scholars (Renninger, 1990, 1992, 2000; Hidi & Renninger, 2006), was not covered in this questionnaire. We did not expect to find a correlation between knowledge and interest because we assumed that young students would have very little knowledge about scientific topics and would have little understanding of the contribution of knowledge to interest. Nevertheless, the learners could have shown some interest that was based on individual and situational sources and was equated mainly with positive feelings (Renninger, 2000). Furthermore, students' low level of knowledge about the topic would allow a better examination of the role of interest.

Three items (2, 6, and 10) of the questionnaire were reversed so that for each item, higher scores reflected greater interest. The alpha reliability coefficient of this questionnaire was .80. In this case too, the total score for topic interest was dichotomized on the basis of the median and used to create two mutually exclusive groups. One was made up of students with higher topic interest ($n = 50$; 29 in the experimental condition and 21 in the control condition), and the other was made up of students with lower topic interest ($n = 44$; 22 in the experimental condition and 22 in the control condition).

Prior knowledge. Eight open-ended questions ascertained participants' preexisting conceptions about light and diffusion (Questions 2, 3, and 7), light and vision (Questions 1, 4, and 5), and light and color (Questions 6 and 8). All questions were of a generative nature (Vosniadou, 1994) and asked students to formulate an explanation for a phenomenon (see the Appendix). Some of these questions were devised by taking into account questions asked in previous studies (Guesne, 1985; Jung, 1986; La Rosa & Mayer, 1991; La Rosa, Mayer, Patrizi, & Vicentini, 1984; Ramadas & Driver, 1989; Ramadas & Shayer, 1987; Watts, 1985) and the grade level of our participants, who were younger than those involved in previous research. Each question was accompanied by a schematic representation of the phenomenon, because much of the teaching of optics in school involves ray diagrams. Diagrams of selected aspects of light–vision phenomena are also very frequent in textbooks discussing light. Some questions also asked the students to add elements to complete a schematic representation. In this case, the elements added and the explanation were considered together, one helping with the understanding of the other. The reliability of open-ended questions was .73 at pretest, .84 at the immediate posttest, and .83 at the delayed posttest.

Reading comprehension. Participants were individually administered an Italian standardized test for fifth grade to measure their expository text reading comprehension skills (Cornoldi & Colpo, 1995) and to tease out their correctness and rapidity in decoding. The test consists of a reading text and 10 multiple-choice questions. Students are asked to read the text silently and individually with no time constraints, but time is considered over when 9/10 of the class have finished answering the questions. Students are allowed to refer to the text whenever they need to in order to minimize the memory load. Some of the answers require information explicitly stated in the text and ask respondents to identify characters (animals, entities, etc.), actions, and events, whereas other answers require inferences.

Reading Materials

The effects of the learning text type on conceptual change were examined by means of two versions of the same text about light. In the traditional text reading condition (control group), students were given a text that combined extracts from common science textbooks (Ajello, Girardet, & Grazzini Hoffman, 1994; Magon, 1996; Saccaro & Signorini, 1996). In the refutational text reading condition (experimental group), students were given a refutational text, which was prepared by modifying the structure of the text used in the former condition. Three parts were added but no other modifications made. Each of these three parts was written to activate, by directly stating and challenging, a specific alternative conception held by the participants. Each part added to the refutational text was written in keeping with the conceptual continuity and text flow. Text coherence was modified as little as possible with the insertion of each part. The three parts did not differ in any aspects of their structure. The first part added addressed the question of the nature and diffusion of light. It was aimed at undermining the conception of a corpuscular nature of light and the conception that the diffusion of light depends on its intensity. The second part added underlined the role of light and its relationship with vision to challenge the naïve conceptions that light alone or light and open eyes are enough to see an object. The third part added was aimed at refuting the idea that color is the property of the object, unrelated to light absorption and reflection phenomena (see the Appendix for excerpts of the traditional and refutational texts).

With these three parts included, the refutational text was much longer than the traditional one. To reduce this discrepancy, the traditional text included additional material that extended and elaborated the information provided. No marginal information was added, which would render the text less focused, therefore disadvantaging students in the control condition. The final version was 481 words, whereas the refutational text was 661 words. Given that the former was still shorter, the control group students were given a further prereading task; that is, they were asked to write down whatever came into their minds on hearing the word *light*. In this way, the amount of time dedicated to the topic was more or less the same for the two groups. Nevertheless, it should be acknowledged that this task, which could activate prior knowledge (i.e., more alternative conceptions about light), could also reduce the likelihood of conceptual change (Alvermann, Smith, & Readence, 1985). However, in this case what the participants wrote, elicited by hearing the word *light,* was not about scientific phenomena that could allow them to activate and focus on alternative representations. The students who had not dealt with light as a scientific topic reported experiences of their everyday life that came to mind. For example, a student's curtains remained open in her bedroom, so she woke up early in the morning before the alarm clock, because there was too much light in the room. Another student described a street that had been dark and was now well lit, which made people happy because they felt more comfortable walking or cycling at night.

Postreading Materials and Tasks

Liking the text. In both reading conditions, students were asked to rate how much they liked the text they had read on a 5-point Likert type scale (1 = *not at all*, 5 = *very much*) and how much they liked to read science texts. These questions were aimed at ascertaining whether there would be a greater preference for the refutational text over the traditional text, which was very similar to any other traditional textbook science text.

Retention questions. Five open questions were asked to assess participants' ability to retain facts presented in the text by referring to famous scientists who, in the past, held different views about light. They were challenging to some extent because they were about these views, but they did not ask for any explanations and could be correctly and completely answered, with no inferences, by retaining information that was explicitly expressed in the text. In addition, the answers could be given independently of the students' own conceptions about light. Retaining what a scientist said about light did not imply any reference to their views. Thus, the responses did not represent deep thinking on the content, as did those aimed at measuring conceptual change, which required explanations on the basis of the students' own views (see the Appendix).

Conceptual change questions. The same generative open-ended questions used to ascertain participants' prior knowledge were asked again at both immediate and delayed posttests to examine any changes in students' conceptions as well as the stability of these changes. Answers to these questions ascertained text understanding at the level of the situation model (Kintsch, 1998), an understanding based on an integration between prior knowledge and knowledge provided by the text (see the Appendix).

Coding

Answers to the open-ended questions, which were asked to measure text retention, were scored 0 to 2 according to their degree of correctness and completeness. No points were given for incorrect answers. One point was assigned if the answer consisted of correct but incomplete information. Two points were assigned if the question was answered correctly and completely. For instance, students were asked, "Where does light come from according to Kepler?" The answer "Light rays come from the eyes" scored 0. The answer "Light comes from a lamp" scored 1. The answer "Light rays come from all light sources, for example, the sun or a candle" scored 2. All answers were coded by two independent raters. Each rater read and scored all answers independently. Interrater agreement calculated as a percentage of agreement on the total of the answers was 94%. Disagreements were resolved in conference through discussion in the presence of a third rater.

Answers to the generative open-ended questions asked at pretest and at immediate and delayed posttests to measure conceptual change were analyzed both qualitatively and quantitatively. For the qualitative analysis, different explanation categories were identified for each of the three topics about light. For the quantitative analysis, the answer categories were scored 0 to 2 according to their degree of correctness and completeness, as were the retention questions. For example, one of the questions about vision, taken from Ramadas and Driver (1989), was the following:

> A child is in a dark room and cannot see anything. When the lights are turned on in the room she sees a book on a table in front of her. How is she now able to see the book? Explain carefully what is happening

> between the book and her eyes. You can draw lines on the diagram to help your explanation. (p. 103)

No points were assigned to unclear or irrelevant answers or to answers expressing alternative conceptions like the following: "The light brightens the book on the table"; "The light brightens up the book. At this point the child can see it. The light illuminates the table well but not all the room"; "When the light is turned on, light rays reach the child's eyes and the book on the table, so she can see it." One point was given for correct but incomplete answers; for example, "The light ray hits the object, so that the child's eye can see it." Two points were given to correct and more complete/elaborated answers; for example, "The rays of the lamp bounce off the book and go to the eyes of the child, who is able to see the book."

All answers were coded by the same two independent raters. Interrater agreement calculated as a percentage of agreement on the total of the answers was 93%. Disagreements were resolved in conference through discussion in the presence of a third rater. Questions are reported in the Appendix.

Procedure

Data gathering took place in three sessions. The topic of light had not been dealt with previously in any of the students' classes. It is a topic studied in fifth grade, so the teachers' cooperation was extremely valuable. In the first session (pretest), the order of tasks was (a) epistemological beliefs questionnaire, (b) pretest generative open-ended questions, and (c) reading comprehension test. The session took about 2 hr. The second session took place about 1 week after the first. In one condition, participants were asked to study the traditional text, whereas participants in the other condition were asked to study the refutational text. After studying the text (immediate posttest), participants were asked to rate their liking of the text they read and the texts they usually read in their schoolbook, and they were asked to answer the text retention questions and the open-ended generative questions. This session also took about 2 hr. The third session (delayed posttest) took place 2 months after the posttest and lasted about 1.25 hr. Participants were again asked the text retention questions and the open-ended generative questions. Between the immediate and the delayed posttests, the topic of light was not discussed at all in the classrooms to avoid interference from other instructional variables.

Results

Four *t* tests, controlled for error rates, were performed first to ensure the equivalence of the groups in the two reading conditions, refutational and traditional text, for all the examined measures. The results show that before the reading tasks, there were no statistically significant differences between the two groups of students for any of the measures: epistemological beliefs (refutational: $M = 37.76$, $SD = 5.78$; traditional: $M = 37.93$, $SD = 5.19$), $t(92) = 0.14$, $p = .88$; topic interest (refutational: $M = 35.55$, $SD = 7.79$; traditional: $M = 36.30$, $SD = 5.99$), $t(92) = 0.51$, $p = .60$; prior knowledge (refutational: $M = 0.29$, $SD = 0.61$; traditional: $M = 0.37$, $SD = 0.92$), $t(92) = 0.48$, $p = .62$; and reading comprehensions skills (refutational: $M = 10.13$, $SD = 2.10$; traditional: $M = 10.51$, $SD = 2.13$), $t(92) = 1.42$, $p = .15$. As expected, prior topic knowledge and interest were not correlated ($r = .01$, $p = .91$).

In all the subsequent statistical analyses, the variables of epistemological beliefs and topic interest were dichotomized for two reasons. First, given the nonlinear relation between the dependent and independent variables, the dichotomization would increase the power of the statistical design. Second, the use of the full range value of the variables would have implied a repeated multivariate analysis with one independent variable (type of text) and three covariates (epistemological beliefs, topic interest, and reading comprehension skills), with unclear outcomes. Because we were interested in maximizing the possibility of attaining results that were as clear and interpretable as possible, we opted for the dichotomized variables. This allowed an analysis that offered a clear interpretation of the differences between the two groups.

Text Retention

A repeated measures analysis of covariance (ANCOVA), with text type (traditional and refutational), epistemological beliefs (less advanced and more advanced), and topic interest (lower and higher) as between-subject variables, with time (immediate posttest and delayed posttest) as the within-subject variable, and with reading comprehension as the covariate, was carried out. It revealed only the effect of the covariate, $F(1, 85) = 6.25$, $p < .05$, $\eta^2 = .07$. This means that at both immediate and delayed posttests, reading comprehension skills correlated significantly with the retention of facts introduced in the text. None of the other variables examined affected this more shallow level of text understanding at the two testing times.

Overall Conceptual Change

Overall changes in explanations about light, vision, and color were measured through a repeated measures ANCOVA with text type (traditional and refutational), epistemological beliefs (less advanced and more advanced), and topic interest (low and high) as between-subject variables, with conceptual knowledge at the three different testing times (pretest, immediate posttest, and delayed posttest) as the within-subject variables, and with reading comprehension as the covariate. From this analysis, the Time × Text Type interaction, $F(2, 84) = 8.31$, $p = .001$, $\eta^2 = .16$, the Time × Topic Interest interaction, $F(2, 84) = 7.18$, $p = .001$, $\eta^2 = .14$, and the Time × Text Type × Topic Interest × Epistemological Beliefs interaction, $F(2, 84) = 4.43$, $p < .05$, $\eta^2 = .09$, emerged. The analysis also revealed that the covariate, reading comprehension ability, correlated significantly with the three scores, $F(2, 84) = 9.98$, $p < .001$, $\eta^2 = .19$.

Regarding the Testing Time × Text Type interaction, students who received information from the refutational text were facilitated in conceptual change much more than those who read the traditional text. The former scored higher than the latter at delayed posttest, but their scores decreased more from the immediate posttest to the delayed posttest.

Regarding the Testing Time × Topic Interest interaction, participants with high interest outscored students with low motivational involvement at both testing times. Moreover, from the immediate to the delayed posttest, the scores of the highly interested students decreased more than those of the less interested students, whose scores remained the same.

From the interaction among all three variables, it emerged that at both testing times, the highest scores for conceptual change were obtained by learners with high topic interest, those with more advanced epistemological beliefs, and those who read the refutational text, although these scores decreased significantly from the immediate to the delayed posttest. Scores for students in the experimental condition with low topic interest but more advanced epistemological beliefs increased slightly at the delayed posttest. The same result emerged for the control condition students with low topic interest and less advanced beliefs about the nature of scientific knowledge. The interaction among all three variables can be seen in Figure 1.

Because the refutational text addressed conceptions about three partly connected phenomena, that is, the propagation of light, the relationship between light and vision, and the origin of color, a finer-grained analysis was also carried out to examine in depth the effect of the independent variables on changes in conceptions about each phenomenon. The next sections present the results of this analysis.

Conceptual Change About the Nature and Propagation of Light

A repeated measures ANCOVA with the same between-subject variables and the same covariate, but with the scores of conceptual knowledge about the nature and propagation of light as within-subject variables, revealed a significant Time × Text Type interaction, $F(2, 84) = 10.07$, $p < .001$, $\eta^2 = .19$. Students who read the refutational text changed their conceptions about these aspects of light much more than students who read the traditional text. The scores for their explanations were higher at both testing times (Table 1). Learner variables did not affect conceptual change, except for the covariate of reading comprehension skills, $F(2, 84) = 7.72$, $p < .01$, $\eta^2 = .13$.

A qualitative analysis identified the conception categories held by students prior to and after text reading (see Table 2). The refutational text was mainly successful in prompting a change in the most common misconception, that is, light as rays that propagate around the light source. It also promoted a change in the alternative conception of light as particles that propagate around the light source. However, not all learners were able to construct scientific knowledge. To illustrate conceptual change due to text reading, which is representative of the data analyzed, we report an example explanation given by a participant (P96, refutational text reading, high topic interest, and more advanced epistemological beliefs) to the third question (see the Appendix). It shows revision of personal conceptions from pretest to posttest.

> Pretest: "I have drawn the light which is still and illuminates a specific point."
>
> Immediate posttest: "I have drawn the light rays that do not meet any obstacle so they diffuse in all directions."

Conceptual Change About Vision

A similar repeated measures ANCOVA, with the scores for conceptual knowledge about the relationship of light and vision as within-subject variables, revealed a significant Time × Text Type interaction, $F(2, 84) = 7.77$, $p = .001$, $\eta^2 = .15$, a Time × Topic Interest interaction, $F(2, 84) = 4.06$, $p < .05$, $\eta^2 = .09$, and a Time × Text Type × Topic Interest × Epistemological Beliefs interaction, $F(2, 84) = 3.41$, $p < .05$, $\eta^2 = .07$. Alternative conceptions about the role of light and its relationship with vision changed more for students who read the refutational text and had high topic interest. At both testing times, the interaction among all three variables showed that more conceptual change was produced by students who read the refutational text and had high topic interest. This interaction also showed that these students had more advanced beliefs about the certainty and development of scientific knowledge (see Table 3). In addition, the ANCOVA revealed a

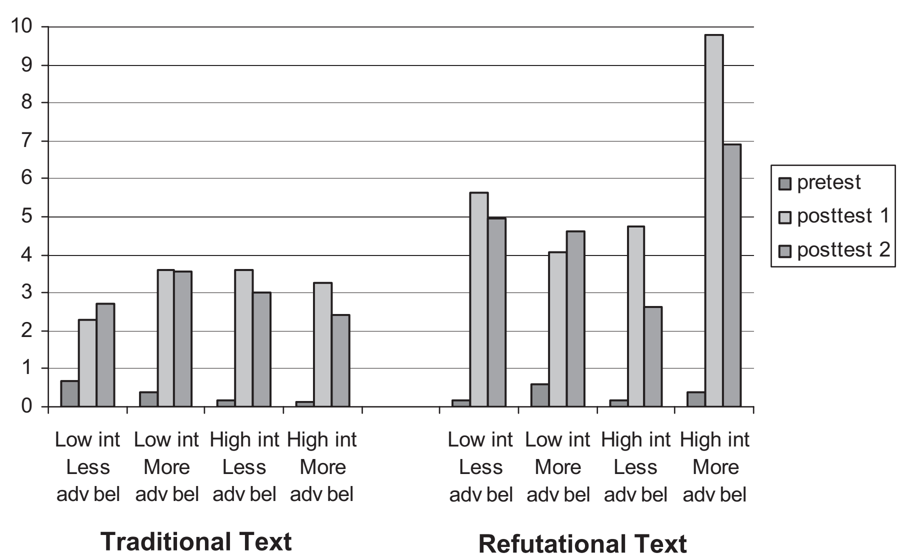

Figure 1. Overall scores for conceptual change showing the interaction between text type, topic interest (int), and epistemological beliefs (bel). adv = advanced.

Table 1
Adjusted Marginal Means and Standard Errors of Explanations About the Nature and Diffusion of Light at the Pretest and the Immediate and Delayed Posttests by Text Type

		Pretest		Immediate posttest		Delayed posttest	
Text type	*n*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Refutational	51	0.28	0.77	2.73	0.25	2.46	0.27
Traditional	43	0.14	0.83	0.97	0.27	0.99	0.29

Note. Adjustment by covariate of reading comprehension.

significant effect of the covariate, reading comprehension skills, $F(2, 84) = 9.54$, $p < .001$, $\eta^2 = .18$.

A qualitative analysis identified the conception categories held by students prior to and after text reading (see Table 4). In this case, the refutational text was especially successful in prompting a change in the common, targeted misconception that as well as light, our eyes have an active role in seeing an object. Not all readers, however, were able to learn the new scientific knowledge from the text. The following is a representative example of conceptual change about light and vision as reflected in the explanations given by a participant (P33, refutational text reading, low topic interest, and less advanced epistemological beliefs) to the first question (see the Appendix).

> Pretest: "Light illuminates the book on the table and she sees it."

> Delayed posttest: "In my opinion the light diffuses in the whole room; a light ray hits the book, it makes the ray bounce off the book, so that it comes to our eyes and we are able to see the colored object."

Conceptual Change About Color

Our last repeated measures ANCOVA, with the scores for conceptual knowledge about color as within-subject variables, revealed only the significant Time × Topic Interest interaction, $F(2, 84) = 3.32$, $p = .05$, $\eta^2 = .07$. Students who reported that they were interested in knowing about light and attributed more importance to the topic were those who changed their naïve conceptions about color more (see Table 5). Only in this analysis did the effect of the covariate, reading comprehension skills, not emerge.

Table 2
Frequency and Percentage (in Parentheses) of Responses to Questions About the Nature and Diffusion of Light at the Pretest and the Immediate and Delayed Posttests by Text Type

	Refutational text ($n = 51$)			Traditional text ($n = 43$)		
Response category and score[a]	Pretest	Posttest 1	Posttest 2	Pretest	Posttest 1	Posttest 2
Question 2						
Not pertinent/unclear (0)	6 (11.8)	5 (9.8)	5 (9.8)	9 (20.9)	6 (14.0)	8 (18.6)
Particles around the source (0)	11 (21.6)	3 (5.9)	3 (5.9)	9 (20.9)	4 (9.3)	3 (7.0)
Rays around the source (0)	31 (60.8)	13 (25.5)	17 (33.3)	20 (46.5)	22 (51.2)	23 (53.5)
Particles and infinite rays (0)	2 (3.9)	—	—	2 (4.7)	1 (2.3)	1 (2.3)
Infinite rays (1)	1 (2.0)	6 (11.8)	8 (15.7)	2 (4.7)	5 (11.6)	4 (9.3)
Infinite rays (2)	—	24 (47.1)	18 (35.3)	1 (2.3)	5 (11.6)	4 (9.3)
Question 3						
Not pertinent/unclear (0)	7 (13.7)	5 (9.8)	6 (11.8)	12 (27.9)	9 (20.9)	12 (27.9)
Particles around the source (0)	14 (27.5)	5 (9.8)	10 (19.6)	9 (20.9)	5 (11.6)	4 (9.3)
Rays around the source (0)	17 (33.3)	9 (17.6)	12 (23.5)	16 (37.2)	15 (34.9)	15 (34.9)
Particles and infinite rays (0)	8 (15.7)	—	1 (2.0)	4 (9.3)	2 (4.7)	1 (2.3)
Infinite rays (1)	3 (5.9)	11 (21.6)	5 (9.8)	2 (4.7)	8 (18.6)	4 (9.3)
Infinite rays (2)	2 (3.9)	21 (41.2)	17 (33.3)	—	4 (9.3)	7 (16.3)
Question 7						
Not pertinent/unclear (0)	26 (51.0)	14 (27.4)	14 (27.4)	15 (34.9)	18 (41.9)	18 (41.9)
Particles around the source (0)	3 (5.9)	1 (2.0)	—	1 (2.3)	1 (2.3)	1 (2.3)
Rays around the source (0)	17 (33.3)	13 (25.5)	13 (25.5)	25 (58.1)	17 (39.5)	17 (39.5)
Particles and infinite rays (0)	1 (2.0)	—	—	1 (2.3)	—	—
Infinite rays (1)	3 (5.9)	13 (25.5)	11 (21.6)	1 (2.3)	7 (16.3)	5 (11.6)
Infinite rays (2)	1 (2.0)	10 (19.6)	13 (25.5)	—	—	2 (4.7)

[a] A score of 0 means no points were attributed to the answer; a score of 1 means a correct answer (e.g., "Light expands in all the surrounding area"); a score of 2 means a correct and more elaborated complete answer (e.g., "Light starts from the candle and illuminates until it meets the first obstacle"). See the Appendix for the content of questions.

Table 3
Adjusted Marginal Means and Standard Errors of Explanations About Light and Vision at the Pretest and the Immediate and Delayed Posttests by Text Type, Topic Interest, and Epistemological Beliefs

Text type, topic interest level, epistemological belief level, and testing time	*n*	*M*	*SE*
Refutational text			
Low topic interest			
Less advanced beliefs			
Pretest	11	0.11	0.10
Posttest 1	11	1.72	0.49
Posttest 2	11	1.28	0.51
More advanced beliefs			
Pretest	11	0.88	0.10
Posttest 1	11	2.37	0.49
Posttest 2	11	1.76	0.50
High topic interest			
Less advanced beliefs			
Pretest	11	0.89	0.10
Posttest 1	11	2.30	0.38
Posttest 2	11	1.20	0.39
More advanced beliefs			
Pretest	18	0.01	0.81
Posttest 1	18	3.94	0.49
Posttest 2	18	2.60	0.50
Traditional text			
Low topic interest			
Less advanced beliefs			
Pretest	10	0.20	0.10
Posttest 1	10	1.55	0.51
Posttest 2	10	1.90	0.53
More advanced beliefs			
Pretest	12	0.33	0.99
Posttest 1	12	1.06	0.47
Posttest 2	12	1.31	0.48
High topic interest			
Less advanced beliefs			
Pretest	8	0.02	0.12
Posttest 1	8	1.19	0.57
Posttest 2	8	0.96	0.59
More advanced beliefs			
Pretest	13	0.13	0.97
Posttest 1	13	1.86	0.45
Posttest 2	13	1.05	0.47

Note. Adjustment by covariate of reading comprehension.

A qualitative analysis identified the conception categories held by students prior to and after text reading (see Table 6). In this case, the refutational text was not powerful in prompting the restructuring of the targeted alternative conception that color is a property of an object. Changes in explanations about color were infrequent and can be illustrated, as an example, by the following participant's answer (P43, refutational text reading, high topic interest, and more advanced epistemological beliefs) to the sixth question (see the Appendix).

> Pretest: "I have drawn an arrow to show that the child is looking at the orange. She sees it as orange because its skin is orange."

> Delayed posttest: "Light, which is made up of the different colors of the rainbow, absorbs all colors but the orange, so the child sees the orange as orange."

Liking the Reading Text

For the control group students, a *t* test to compare ratings of how much they liked the text they read revealed no significant difference between the two ratings, $t(92) = 1.30$, $p = .195$. Students perceived the text they had just read in the same way as any other science text they were familiar with. On the contrary, for the experimental group, who read the refutational text, a *t* test revealed a significant difference, $t(92) = 4.16$, $p < .001$. The unusual text ($M = 4.24$, $SD = 1.05$) just read, which stated and challenged their conceptions, was liked more than the normal textbook science texts ($M = 3.51$, $SD = 1.17$).

Discussion

This study was aimed at examining the interplay between instructional text and learner variables that may affect conceptual change. Three variables were examined, which had been investigated separately or in pairs in previous research: the structure of the text to be read to gain new knowledge, epistemological beliefs, and topic interest. Two types of instructional texts were used: an ordinary expository science text whose primary function was to give new information and a refutational text that not only gave new, correct information but also explicitly stated and refuted alternative conceptions by presenting the scientific conceptions as viable alternatives. It should be underlined that, as in most previous research on knowledge restructuring, in this study epistemological beliefs reflect more or less advanced representations about only two aspects of scientific knowledge, that is, its nature and its development (simple and certain vs. complex and continuously evolving), and not epistemological beliefs at large. However, these two belief dimensions are the most pertinent to the focus of the study. Topic interest reflects lower or higher affective orientation toward the topic examined.

Our first research question examined whether participants' text retention would be affected by text type, epistemological beliefs, topic interest, and/or their interaction. The findings confirm our hypothesis because none of the examined variables affected the shallow level of text understanding related to retention of factual information. Only the covariate, reading comprehension ability, correlated with the dependent variable.

The second research question examined whether students' overall conceptual change as well as the various aspects of light addressed—which were reflected in their answers to open-ended questions—would be affected by text type, epistemological beliefs, and topic interest. Findings partially confirm our hypotheses. Overall, the positive effect of reading the refutational text confirms previous research (Guzzetti et al., 1993, 1997) and, in particular, confirms an investigation that involved fifth graders learning about energy (Diakidoy et al., 2003), although it did not explicitly address pre- and postreading conceptions about the topic.

Topic interest was also a resource in the knowledge revision process. It must be pointed out that the motivational variable did not correlate with prior knowledge, as emerged from previous studies carried out with much older students (Andre & Windschitl, 2003; Venville & Treagust, 1998). Thus, a higher degree of interest did not mean a higher number of initial alternative conceptions. This could have been because our participants' initial knowledge was generally very limited, so high interest in the topic could be

Table 4
Frequency and Percentage (in Parentheses) of Responses to Questions About Light and Visions at the Pretest and the Immediate and Delayed Posttests by Text Type

	Refutational text (n = 51)			Traditional text (n = 43)		
Response category and score[a]	Pretest	Posttest 1	Posttest 2	Pretest	Posttest 1	Posttest 2
		Question 1				
Not pertinent/unclear (0)	1 (2.0)	—	1 (2.0)	1 (2.3)	4 (9.3)	1 (2.3)
Light illuminates the object (0)	20 (39.2)	13 (25.5)	11 (21.6)	21 (48.8)	8 (18.6)	8 (18.6)
Light illuminates the object and the eyes see it (0)	26 (51.0)	7 (13.7)	18 (35.3)	11 (25.6)	11 (25.6)	18 (41.9)
Light illuminates both the object and the eyes (0)	4 (7.8)	1 (2.0)	5 (9.8)	10 (23.3)	6 (14.0)	8 (18.6)
Light goes from the object to the eyes (1)	—	—	—	—	—	—
Light bounces off the object into the eyes (2)	—	30 (58.8)	16 (31.4)	—	14 (32.6)	8 (18.6)
		Question 4				
Not pertinent/unclear (0)	16 (31.4)	8 (15.7)	8 (15.7)	13 (30.2)	12 (27.9)	9 (20.9)
Light illuminates the object (0)	4 (7.8)	16 (31.4)	15 (29.4)	4 (9.3)	13 (30.2)	13 (30.2)
Light illuminates the object and the eyes see it (0)	29 (56.9)	10 (19.6)	18 (35.3)	23 (53.5)	15 (34.9)	16 (37.2)
Light illuminates both the object and the eyes (0)	—	—	—	2 (4.7)	—	—
Light goes from the object to the eyes (1)	2 (3.9)	—	—	1 (2.3)	—	—
Light bounces off the object into the eyes (2)	—	17 (33.3)	10 (19.6)	—	3 (7.0)	5 (11.6)
		Question 5				
Not pertinent/unclear (0)	8 (15.7)	5 (9.8)	7 (13.7)	9 (20.9)	7 (16.3)	6 (14.0)
Light illuminates the object (0)	38 (74.5)	33 (64.7)	29 (56.9)	30 (69.8)	24 (55.8)	26 (60.5)
Light illuminates the object and the eyes see it (0)	5 (9.8)	3 (5.9)	7 (13.7)	3 (7.0)	6 (14.0)	5 (11.6)
Light illuminates both the object and the eyes (0)	—	1 (2.0)	—	—	—	—
Light goes from the object to the eyes (1)	—	—	—	—	—	—
Light bounces off the object into the eyes (2)	—	9 (17.6)	8 (15.7)	1 (2.3)	6 (14.0)	6 (14.0)

[a] A score of 0 means no points were attributed to the answer; a score of 1 means a correct answer; a score of 2 means a correct and more elaborated, complete answer. See the Appendix for the content of questions.

expressed by students who knew very little about light and not only by those who had high (alternative) prior knowledge. When interest is equated with positive feelings in particular, it may be associated with a low level of content knowledge or little awareness about the contribution of knowledge to interest (e.g., Renninger, 2000).

The main effect of epistemological beliefs did not emerge. However, a significant interaction among convictions about the nature and stability of scientific knowledge, topic interest, and text type, in relation with testing time, has been found generally. As hypothesized, an effective combination of all three factors emerged, although the effect was modest. More conceptual change was produced by students who read the refutational text, those who had more advanced epistemological beliefs, and those with high topic interest. Although when compared with the others these students' performances decreased from the immediate to the delayed posttest, they were still the highest 2 months after reading the instructional text. This outcome could have been due to the powerful combination of topic interest, which promotes attention arousal, and the other two resources, epistemological beliefs and refutational text. The latter have the potential to help students recognize, more or less directly, the limitations of their own conceptions, to be dissatisfied with them, and to try to make sense of the new knowledge. The advantageous interaction among the three factors may be related to the notion of intentionality in conceptual change (Sinatra & Pintrich, 2003a). These factors could help make learning through conceptual revision a goal to be deliberately pursued (Hynd, 2003; Mason, 2003) to improve current understanding of the phenomena examined.

The interaction among epistemological beliefs, topic interest, and text type sustains deep processing (Alexander et al., 1994). However, processing during text reading (Kardash & Howell, 2000) was not the focus of the current study, and we do not have direct information about whether readers with different epistemo-

Table 5
Adjusted Marginal Means and Standard Errors of Explanations About Color at the Pretest and the Immediate and Delayed Posttests by Topic Interest

		Pretest		Immediate posttest		Delayed posttest	
Topic interest	n	M	SE	M	SE	M	SE
High	50	0.02	0.05	1.02	0.18	0.70	0.18
Low	44	0.15	0.05	0.45	0.18	0.50	0.19

Note. Adjustment by covariate of reading comprehension.

Table 6
Frequency and Percentage (in Parentheses) of Responses to Questions About Color at the Pretest and the Immediate and Delayed Posttests by Text Type

	Refutational text (n = 51)			Traditional text (n = 43)		
Response category and score[a]	Pretest	Posttest 1	Posttest 2	Pretest	Posttest 1	Posttest 2
			Question 6			
Not pertinent/unclear (0)	8 (15.7)	16 (31.4)	15 (29.4)	14 (32.6)	13 (30.2)	19 (44.2)
Color is a property (0)	28 (54.9)	12 (23.5)	18 (35.3)	14 (32.6)	11 (25.6)	9 (20.9)
Light gives color (0)	7 (13.7)	10 (19.6)	9 (34.6)	5 (11.6)	6 (14.0)	6 (14.0)
Eyes see colors (0)	5 (9.8)	—	1 (2.0)	4 (9.3)	—	—
Light and eyes allow colors to be seen (0)	3 (5.9)	—	—	4 (9.3)	—	1 (2.3)
Objects reflect color (1)	—	7 (13.7)	3 (5.9)	2 (4.7)	8 (18.6)	3 (7.0)
Light hits the object reflecting color into the eyes (2)	—	6 (11.8)	5 (9.8)	—	5 (11.6)	5 (11.6)
			Question 8			
Not pertinent/unclear (0)	7 (13.7)	15 (29.4)	10 (19.6)	10 (23.3)	10 (23.3)	10 (23.3)
Color is property (0)	30 (58.8)	16 (31.4)	18 (35.3)	15 (34.9)	15 (34.9)	15 (34.9)
Light gives color (0)	5 (9.8)	7 (13.7)	9 (17.6)	7 (16.3)	7 (16.3)	8 (18.6)
Eyes see colors (0)	7 (13.7)	1 (2.0)	2 (3.9)	5 (11.6)	2 (4.7)	2 (4.7)
Light and eyes allow colors to be seen (0)	2 (3.9)	1 (2.0)	—	5 (11.6)	—	—
Objects reflect color (1)	—	5 (9.8)	7 (13.7)	1 (2.3)	5 (11.6)	3 (7.0)
Light hits the object reflecting color into the eyes (2)	—	6 (11.8)	5 (9.8)	—	4 (9.3)	5 (11.6)

[a] A score of 0 means no points were attributed to the answer; a score of 1 means a correct answer; a score of 2 means a correct and more elaborated complete answer. See the appendix for the content of questions.

logical beliefs and topic interest process text differently in the two reading conditions. As an alternative explanation, it could be speculated that these students might have—without deep processing—simply noted discrepancies in conceptions. However, this alternative seems less likely in light of the literature on conceptual change, which underlines that it is a demanding process in many respects. In any case, further research is needed to examine the mechanisms through which the beneficial effects of these factors are activated.

In addition, an overall compensation effect of the instructional and motivational variables emerged. Reading an innovative text, which activates and challenges readers' prior knowledge, unlike traditional science texts, compensated for low levels of interest in the topic and less sophisticated convictions about scientific knowledge. Overall, these data confirm a previous study on the relationship between epistemological beliefs and reading a refutational text, from which a powerful combination of the personal and instructional variables also emerged (Mason & Gava, 2007).

The overall outcomes were also found in the finer grained analysis of the change in conceptions about the second phenomenon considered: light in relation to vision. Refutational text and topic interest as separate variables, as well as the interaction between all three variables tested, affected how misconceptions were overcome in favor of the scientific explanation, although not all students abandoned their alternative ideas.

The analysis of conceptual change about the first phenomenon of light addressed, its nature and diffusion, revealed that it was affected only by the type of text read. Specifically, the refutational text succeeded in prompting change in the most commonly held misconceptions, that is, light as rays or particles that propagate only around the source.

A finer grained analysis of conceptual change about the third phenomenon addressed, color, revealed that the refutational text was relatively ineffective in advancing students' scientific knowledge. Only high topic interest helped participants learn more about the scientific conception of the origin of an object's color. The alternative idea of color as a property was the most difficult to change. An explanation for this outcome cannot refer to differences in the refutation provided in that part of the refutational text, because it did not differ in any respect from the previous two parts that were more effective. It can be argued that the scientific conception of the origin of color seems not only as abstract and complex as the others, especially for young students, but also counterintuitive. It is particularly hard to understand that size and shape are properties of an apple but color is not and that its redness must be conceived in relation to the light that the apple reflects. It should be pointed out that in the history of science, the idea that light is not white or yellow but rather contains all colors and the idea that materials absorb some of these colors while reflecting others appeared later than the currently accepted ideas about the nature and propagation of light as well as about vision phenomena.

Furthermore, the correlation between reading comprehension ability and change of conceptions highlights, once again, the importance of this ability in academic learning. Improving students' reading comprehension is, in any case, an essential way to support their conceptual learning from a text.

The overall decreased performance from the immediate to the delayed posttest could be expected, to some extent. The higher decrease in the scores of students with high interest who were in the refutational text condition (see Figure 1) may be explained by a prereading topic interest that was mainly an expression of situational interest elicited by the words and sentences that presented the topic. Topic interest measured in the study could therefore be mainly the expression of a triggered situational interest, that is, a characteristic of the first phase of interest development (Hidi & Renninger, 2006).

The overall increased performance from the immediate to the delayed posttest by students in the experimental condition (those with more advanced epistemological beliefs and low topic interest) and students in the control condition (those with less advanced epistemological beliefs and low topic interest) cannot be explained by further teaching about light, because the teachers did not deal with this topic during the 2-month period that elapsed between the immediate and delayed posttest. It could be speculated that studying other physics topics may have indirectly helped the students to understand the light phenomena better. However, this hypothesis is rather weak because teachers covered the human cardiovascular and respiratory systems in the interim 2-month period. As an alternative, it could be speculated that students might have had further opportunities to learn about light during the interval by discussing the answers with each other or with their parents and other knowledgeable adults. To some extent, they could have therefore processed the target concepts in the period between the two posttests, perhaps also supported by an increased interest in the topic triggered by the text and questions (Hidi & Renninger, 2006; Renninger et al., 2002).

The third research question asked if students liked the refutational text more than the traditional one. As hypothesized, the refutational text, which helped more in the revision of preexisting conceptions, was perceived as more likeable than the typical textbook text. This outcome is in line with previous research (Guzzetti et al., 1995). Reading a text that made their representations explicit but also highlighted their limitations in favor of scientific ones was a more likeable activity than reading a typical scientific text that transmits knowledge. In this regard, perception of the ease of a learning text could be a key factor in text liking.

Finally, it should also be pointed out that this study examined conceptual change in a complex topic as a consequence of reading one text, and this is a limitation. However, this is what happens in regular classrooms, at least in Italy, from the last years of primary school onward. New knowledge has to be acquired mainly from text and picture reading, especially when abstract concepts are dealt with and the possibilities of experimentation in the classroom are very limited. We agree that conceptual understanding in physics is the product of a gradual and complex process that requires time (Stathopoulou & Vosniadou, 2007). A deeper and more complete understanding of the topic, even at the fifth-grade level, certainly requires more learning activities than the study of one text. Nevertheless, reading a refutational text can be considered a productive starting point for a long and demanding process.

Conclusion

To conclude, this study documents the role of two learner factors considered in theory by Pintrich and colleagues (Pintrich, 1999; Pintrich et al., 1993) as possible motivational resources for the multifaceted process of conceptual change. These factors, epistemological beliefs and interest, may interact with the instructional material. Higher topic interest was found to be effective in itself and in the interaction with epistemological beliefs and the text type to be learned. A refutational text was also found to facilitate students' understanding of new concepts even when the characteristics of the participants examined were not supportive. This outcome leads us to highlight the potential of refutational texts, especially for the acquisition of concepts that cannot be presented in the classroom through observation and experimentation. The use of refutational texts could also increase students' situational interest (Hidi, 1990; Krapp, Hidi, & Renninger, 1992; Schraw & Lehman, 2001), which is triggered by specific features of a stimulus or situation, such as text characteristics. In this regard, research has documented that potential situational interest sources are ease of comprehension, text cohesion, concreteness, vividness, engagement, and emotiveness. The most effective sources of situational interest in text learning were found to be ease of comprehension, vividness, and concreteness (Sadoski, 2001; Schraw et al., 1995; Schraw, Flowerday, & Lehman, 2001). It is more likely that a refutational, rather than a traditional, text would be perceived as having these characteristics.

More sophisticated beliefs about the certainty and development of scientific knowledge were found to be effective when these beliefs interacted with all other variables examined. That is, they were best as resources in conjunction with attention arousal, which was stimulated by topic interest, and in relation to reading a text that helped students recognize the limitations of their conceptions and the value of scientific ones. Activities and contexts devised to sustain the development of beliefs about the nature of knowledge are more or less indirect ways to favor the knowledge revision process (Mason, 2002).

In summary, the interplay of factors in text learning that emerged from this study indicate that we have moved beyond cold conceptual change, at least to some extent, and are following the warming trend (Sinatra, 2005). The implications of our findings for conceptual change research highlight that new models of knowledge restructuring must take into consideration the complexity of the process, that is, its multifaceted interactive nature (Sinatra & Mason, in press). Models that focus only or mainly on one of the various factors involved in the process cannot account for this complexity or serve as powerful tools for implementing feasible educational interventions aimed at effectively promoting disciplinary knowledge construction and reconstruction in the classroom. It has been recognized that the progress of the research in this multidimensional arena regarding conceptual change may not always be certain and stable (Alexander & Sinatra, 2007). Nevertheless, it is compelling to follow the warming trend (Sinatra, 2005) to increase psychologists' understanding of the complex interplay among key factors underlying conceptual change in the classroom.

From the standpoint of science learning, our findings highlight that if learners hold alternative conceptions, these must be identified in order to tailor instruction to their need for more or less radical knowledge restructuring. The disciplinary material to be learned, for example, the texts to be studied, must be carefully prepared to trigger situational interest. If sustained, this may evolve into a maintained situational interest and gradually into an individual interest (Hidi & Renninger, 2006). This means increasing the likelihood that the new science content is integrated, and not just juxtaposed, into the students' network of conceptions. However, increasing the level of students' understanding of scientific phenomena does not mean that science teaching processes must focus only on conceptual structures, those of the learners, which very often need to be restructured, and those of the disciplinary domain, which are to be acquired. Other noncognitive factors that play an important role in learning processes (motivation in particular) should be taken into consideration. Learners' epistemological representations of the nature of the scientific knowledge they are dealing with, as well as their interest in the content of the knowledge they are asked to understand, are only two of the other factors that affect conceptual change in the classroom.

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(*Appendix follows*)

Appendix

Questionnaires, Open-Ended Questions, and Excerpts From the Texts Used in the Study

The Two Scales Used to Measure Epistemological Beliefs About the Certainty and Development of Science

These two scales are taken from Conley et al.'s (2004, pp. 203–204) questionnaire.

Certainty

All questions in science have only one right answer.

The most important part of doing science is arriving at the right answer.

Scientists know pretty well everything about science; there is not much more to know.

Scientific knowledge is always true.

Once scientists have the result of an experiment, that becomes the only answer.

Scientists always agree about what is true in science.

Development

Some ideas in science today are different than what scientists used to think.

The ideas in science books sometimes change.

There are some questions that even scientists cannot answer.

Ideas in science sometimes change.

New discoveries can change what scientists think is true.

Sometimes scientists change their minds about what is true in science.

The Questionnaire Used to Measure Topic Interest

1. I would be excited about studying light in science classes.
2. I think that there are many more relevant topics than light to learn about in science classes.
3. I think it is important to know what the light we see is made of.
4. If I came across a TV program that talked about light and colors, I would be keen to understand it.
5. I think that during science classes some time could be devoted to talking about light and colors.
6. I am not interested in knowing more scientific aspects of light.
7. I think that light is a difficult but worthwhile topic of science.
8. I would get involved in knowing how we can see the objects around us.
9. I am keen to know what light really is and its characteristics.
10. Knowing how we can see the different colors of objects is not important to me.

Open-Ended Questions to Measure Text Retention

1. Where does light come from according to Euclid?
2. How does light propagate according to Euclid?
3. Where does light come from according to Kepler?
4. What happens when a light ray hits an object according to Kepler?
5. What did Newton discover about light?

Open-Ended Questions to Measure Conceptual Change (Deep Text Understanding)

Each question included a diagram, omitted here because of space restrictions.

1. A child is in a dark room and cannot see anything. When the lights are turned on in the room she sees a book on a table in front of her. How is she now able to see the book? Explain carefully what is happening between the book and her eyes. You can draw lines on the diagram to help your explanation (from Ramadas & Driver, 1989, p. 103).
2. It is a dark moonless night. You see a small lamp shining far away. Show where there is light in this drawing. Then, explain why you think that the light is where you drew it (from Ramadas & Driver, 1989, p. 36).
3. In this diagram there is a candle. Draw the light of the candle to show what happens when the candle burns. Explain what you have drawn.
4. Imagine that a person enters a room where there is the candle burning. The person stays in a corner. In your opinion, can the person see the candle? Draw, and then explain what happens.
5. The child in this diagram uses the slide projector to look

at slides of when he was younger. Draw what happens when the projector is turned on. Then, explain how the child is able to see the slides (from Watts, 1985, p. 185).

6. Mark is looking at an orange on the table. Explain why he sees the orange as an orange color.

7. On a clear night a car is parked on a straight street with the lights turned on. A pedestrian who stops on the street can see the car's lights. In the diagram the street is divided into four sections. In which parts is there light? Explain your answer (from La Rosa & Mayer, 1991, p. 197).

8. Marta is looking at the new yellow t-shirt that she got as a present. Explain why she sees it as a yellow color.

Excerpt From the Traditional Expository Text

Thanks to Kepler's studies, we now know that light diffuses in a straight line in all directions. Light moves from its source along infinite straight paths called "rays". It continues to diffuse until it meets an object. All bodies that emit light (e.g., the sun and stars) are called primary light sources. In contrast, the bodies that receive light are called secondary light sources. When the light rays hit an object, they bounce off it and reach our eyes.

Excerpt From the Refutational Text

Thanks to Kepler's studies we now know that light diffuses in a straight line in all directions. Some children, however, believe that light diffuses into the environment around the light source only up to a certain point. They believe this because they think that light gets used up as it moves further from the source. If you also think in this way, your conception is not correct. Light moves away from its source along infinite straight paths that are called "rays". It continues to diffuse until it meets an object. The area around the light source appears brighter to us only because there the light rays are closer together, while they broaden as they diffuse in all the surrounding area. When the light rays hit an object, they bounce off it and reach our eyes.

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