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Using Elaborative Interrogation To Help Students Overcome Their Science Misconceptions

Vera Ella Woloshyn

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Abstract

The experiments reported here investigated whether a question-answering strategy called elaborative-interrogation would facilitate children's acquisition of science facts. Of particular interest was whether the strategy would help students acquire facts that addressed their inaccurate beliefs, or what are otherwise known as misconceptions. Across two experiments, 140 students in grades 6 and 7 were asked to process individually presented statements. Half of these statements were consistent with their prior knowledge, whereas the remaining facts were inconsistent (i.e., subject to misconceptions). Half of the students in each grade were instructed to read the sentences aloud at a rate that allowed them to understand that the facts were true (reading-control). The remaining students were instructed to use their prior knowledge to answer why each fact was true (elaborative-interrogation). Two tests of recall (free and cued) and two tests of recognition (immediate and 14-day sentence selection questionnaires) followed. Experiment-2 subjects also completed recognition tests at 75-day and 180-day intervals. Elaborative-interrogation subjects performed significantly better on all memory measures than did reading-controls. The quality of elaborative-interrogation study responses did not
significantly affect retention. All students had greater difficulty recognizing facts that addressed common misconceptions than novel facts, although elaborative-interrogation subjects expressed greater confidence in their correct selections than did reading-controls. It was concluded that elaborative-interrogation truly enhanced learning.
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Using Elaborative Interrogation to Help Students Overcome Their Science Misconceptions

Knowledge of the world is believed to play an important role in the acquisition and retention of novel information, with many prominent educational theorists advocating that prior knowledge is the most important single factor that influences learning (e.g., Ausubel, 1968). Investigations conducted in the last two decades have demonstrated that prior knowledge is an important factor in text learning (e.g., Holland, 1975; Ryan, 1981). In fact, prior knowledge appears to be more important than reading expertise when learning from text (e.g., Recht & Leslie, 1988; Ryan, 1981). However, the impact of prior knowledge when reading varies. When prior knowledge is consistent with information presented in text, learning is often facilitated. When prior knowledge is inconsistent with information provided in text, learning is often impeded. In this sense, prior knowledge has been referred to as a "double-edged sword" (Schneider & Pressley, 1989).

Prior Knowledge Facilitates Learning

Having relevant prior knowledge about to-be-learned content can enhance both comprehension and retention of that information (e.g., adults: Bransford, Barclay, Franks, 1972; Bransford & Johnson, 1973; Dooling & Lachman, 1971; Johnson, Bransford & Solomon, 1973;
children: Pearson, Hansen, & Gorden, 1977; Pichert & Anderson, 1977). For example, Brown and her colleagues (Brown, Smiley, Day, Townshead, & Lawton, 1977) demonstrated that prior knowledge can positively influence young children's acquisition of text information. These authors provided students in grades 2, 4, and 6, with an original orienting passage about a fictitious group of people called the Targa. One-third of the children learned that the Targa were peaceful Eskimos, whereas another third learned that they were hostile Indians. The remaining children acted as controls and were given information about Spanish people. One week later, the students were asked to read the critical passage "Tor of the Targa." No explicit connection was drawn between the text and the orientation session. Thus, any relating of previously encountered information to the target passage was initiated by the students.

Following the reading of the study passage, the children were asked to recall the story. The session ended with students answering ten questions. Six of these questions tapped explicit story information (e.g., the age of the main character), whereas the remaining four questions tapped ambiguous information (e.g., description of the Targa's hunting territory). After each question, the children were asked to indicate whether their answer was contained in the story or was something that they
already knew.

Main effects of grade and orientation were significant. More information was recalled by students who were in senior grades. Furthermore, students who had learned about the Targa one week prior to studying the critical passage recalled more text information than did control subjects. Students with prior knowledge about the Targa also used that information to embellish their recall, with the number of orientation intrusions also increasing as a function of grade. However, the children did not seem to be aware that they were distorting recall. When asked where they had acquired the responses to the ambiguous posttest questions, the students indicated that, for 80% of the queries, the answers were stated in text.

The most probable manner in which prior knowledge enhances learning is by providing learners with information that makes novel material more meaningful. Presumably, information that is processed in a very meaningful fashion is more readily retained than information that is processed without meaning, or in a less meaningful fashion (e.g., Craik & Lockhart, 1972; Glover, Rankin, Langner, Todero, & Dinnel, 1985). However, the exact mechanism(s) by which prior knowledge makes information more meaningful are unclear.

One possibility is that prior knowledge increases learners' expectations for a sequence of events.
Alternatively, prior knowledge might provide learners with a comparison base for novel information (i.e., learning by analogy; e.g., Glynn, 1988). Prior knowledge might also provide learners with an organizational strategy for storing incoming information. When the learner wishes to retrieve study information, this strategy would be activated. Even if the critical information was not available at retrieval, accessing relevant prior knowledge might provide learners with alternative concepts that could be substituted for the original information (i.e., the learner could make an educated guess). Although there is no guarantee that the substituted information would constitute a correct response, the probability of success presumably is better than with an uneducated guess. Finally, prior knowledge might provide learners with information that is critical for comprehension and that might otherwise be overlooked or missing in the text.

Unfortunately, simply having relevant prior knowledge that is consistent with to-be-learned text does not always ensure enhanced comprehension. Prior knowledge needs to be accessed or activated in order to facilitate comprehension and retention of text materials. Unless given specific prompts to activate relevant prior knowledge, people often fail to use this information during study (e.g., Christopoulous, Rohwer, & Thomas, 1987; Pressley, McDaniel, Turnure, Wood, & Ahmad, 1987; Pressley
et al., 1988). For example, unless they were instructed to do so, Canadian school children reading facts about animals indigenous to Canada failed to enhance their study with basic knowledge of these animals or Canada (Wood, Pressley, & Winne, 1990). Thus, educators need to provide students with explicit prompts to use relevant prior knowledge when studying.

**Prior Knowledge Impedes Learning**

Activation of prior knowledge does not always facilitate learning. When the learner's prior knowledge is inconsistent with information presented in text, this knowledge usually impedes text acquisition (e.g., Alvermann, Smith, & Readence, 1985; Hynd & Alvermann, 1986; 1987; Lipson, 1982; 1983; Smith, Readence, & Alvermann, 1984). In fact, there is only one known study that suggests otherwise (Peeck, van den Bosch, & Kreupeling, 1982).

Peeck et al. (1982) instructed Dutch children in grade 5 to activate relevant background knowledge by brainstorming about foxes (activators) or activate irrelevant information by brainstorming about American farms (nonactivators) prior to reading a target passage about a fictitious animal, the "American Heath Fox." Some of the passage statements were consistent with children's general fox knowledge, whereas other statements were inconsistent with children's existing knowledge. Peeck et
al. found that children who activated information about foxes before reading the critical passage retained more text ideas that were inconsistent with their general fox knowledge than did children who activated information about farms. That is, generating information inconsistent with text appeared to facilitate learning of target facts.

In contrast to Peeck et al. (1982), the majority of researchers have found that, when students' prior knowledge is contradicted by text, learners allow their existing knowledge to override the presented information (e.g., Alvermann, et al., 1985; Lipson, 1982; Smith, et al., 1984). For example, Smith and her associates either left untouched or manipulated sections of an untaught science text to produce statements that were consistent or inconsistent with students' prior knowledge. For instance, the compatible statement, "The bumblebee has a stinger that can cause pain or death to other insects and birds," was changed to the incompatible statement, "The bumblebee makes a noise that can cause pain or death to other insects and birds." Half of the participants were instructed to activate background information about insects and birds prior to reading, whereas the remaining students were instructed to activate information that was irrelevant to the study materials -- in this case, information about volcanoes.

Students who activated relevant background
information about insects and birds prior to reading the compatible text recalled more passage information than did nonactivators. Activation of knowledge that was consistent with the studied text facilitated learning. However, activators who read incompatible text recalled less of the altered passage than did nonactivators who read incompatible text. In other words, the activation of information that was incompatible with text impeded learning.

While the findings of Smith et al. (1984) are unquestionable -- children who activate prior knowledge that is incompatible with text information retain less passage information than do children who activate knowledge that is consistent with presented text -- the benefits of having students study inaccurate facts are unclear. Using true statements only, Alvermann and her colleagues (Alvermann et al., 1985) replicated Smith et al.'s findings. These authors selected two sections of text such that one passage, "The Rattlesnake," contained information that was consistent with learners' prior knowledge, and the other, "The Sun," contained information that was inconsistent with learners' existing knowledge. Grade 6 students were assigned to either activation or nonactivation conditions. Students assigned to the activation condition were asked to brainstorm about the to-be-learned topics, whereas students assigned to the
nonactivation condition were asked to think about unrelated topics. After six minutes, the students were instructed to read and study the target passages. Text acquisition was assessed via free recall and multiple choice tests.

Analysis of recall data revealed that students assigned to the nonactivation condition recalled more ideas from the incompatible passage than did students assigned to the activation condition. The groups did not differ in the number of compatible text ideas recalled.

Activation students' prototypes were also analyzed. Although there were no significant differences in the number of ideas activated for either topic, more sunlight ideas were judged to be incompatible with the sun passage than were rattlesnake ideas with the snake passage (i.e., 31% versus 6% respectively). Furthermore, students who activated ideas that were inconsistent with the information presented in text retained their inaccurate beliefs after study. Specifically, 100%, 75%, and 67% of students who activated contrary ideas about the sun's colour, reflecting ability, and heat, respectively, expressed those same beliefs at recall. For example, although the sun passage explicitly stated that the sun is made of every colour mixed together (i.e., red, orange, yellow, green, blue, and violet), students who contended that the sun was only red or only orange prior to study
retained that belief after reading. Reading text had little influence in changing students' inaccurate beliefs.

Prior knowledge does not have to be explicitly activated in order to impede learning. Lipson (1982) had grade 3 students of average and below average reading ability complete a 48-item science and social science pretest questionnaire. The questionnaire consisted of true and false sentence pairs, with students instructed to select the statement that they believed was accurate. The children were told to skip test items for which they were unsure of the correct response. Using data from the questionnaire, Lipson was able to calculate students' prior knowledge for to-be-learned text passages. One week later, students were presented with eight expository passages (one passage for each topic covered at pretest). Students were instructed to read the passages carefully as they would be asked about the story information subsequently. After reading, the children completed the science questionnaire for the second time.

In order to assess the relationship between prior knowledge and fact acquisition, students' pretest and posttest questionnaire scores were converted into conditional probabilities. Specifically, the probability of a correct response was calculated for three categories of prior knowledge: correct, incorrect, and unknown. Analysis of the conditional probabilities revealed that
prior knowledge was a major source of variance in posttest performance. Not surprisingly, students were more likely to select the correct statement at posttest if they already knew the correct solution at pretest. Of greater importance to this study, subjects were more likely to select the correct statement when they did not know this response at pretest (i.e., they left the question blank) versus when they answered the pretest question incorrectly. These findings suggest that the students relied more extensively on prior knowledge than text information when answering posttest questions.

That students enter the classroom with pre-existing, often inaccurate, prior knowledge is not surprising. There are many different means by which students may acquire both accurate and inaccurate knowledge. For example, children can acquire knowledge from conversation with peers and elders, television, reading, everyday experiences, and common sense (e.g., Alvermann & Hynd, in press; Champagne, Klopfer, & Gunstone, 1982; Deadman & Kelly, 1978; Eaton, Anderson, & Smith, 1984). In academic settings, some misconceptions may be perpetuated by teachers and textbooks that do not help students differentiate between scientific concepts and everyday experiences (Barrass, 1984).

Regardless of how prior knowledge is acquired, it is clear that this knowledge does not always enhance text
learning. Facilitation appears to be largely dependent on whether prior knowledge and text information are compatible. If prior knowledge is consistent with text, then activation of relevant information usually enhances text acquisition. However, if children's prior beliefs are inconsistent with text, students usually allow their prior knowledge to override written information and impede text learning.

It is unclear why children (or for that matter adults; e.g., Hynd & Alvermann, 1986; 1987) allow inaccurate prior knowledge to override text. The problem is reminiscent of proactive interference where a prior association impedes the acquisition of a novel response to an old stimulus (e.g., Postman & Gray, 1977; Slamecka, 1961; Underwood & Ekstrand, 1966; 1967; Underwood & Freund, 1968; Wessells, 1982; Wingfield & Byrnes, 1981). Specifically, subjects who participated in proactive interference learning paradigms were asked to retain the association A–C following the acquisition of A–B. The typical finding was that learning of A–B impeded acquisition of A–C. It was suggested that difficulties recalling new associations were partially due to an inability to differentiate which list had been learned most recently. In fact, proactive inhibition was reduced when measures were taken to enhance list discrimination (e.g., temporal cues; Underwood & Ekstrand, 1967;
Underwood & Freund, 1968; recalling both B and C responses; Postman & Gray, 1977; and increasing the amount of prior learning; Slamecka, 1961). Therefore, one possibility why students let prior knowledge override text information is that they are unable to differentiate between their prior associations and those presented in the text. If so, learning of text may be enhanced by ensuring that new information is encoded in an especially distinctive manner (Wessells, 1982).

Another possibility is that students assume that the text will reinforce their existing conceptions, and thus, monitor incoming information in a superficial manner (i.e., students do not take the time or invest the effort to read the text carefully). The process of activating prior knowledge may also reinforce students' incorrect beliefs (e.g., Alvermann, & Hynd, in press). Under certain circumstances, information that is self-generated is better retained than information that is provided by an experimenter (e.g., Jacoby, 1978; Schwartz, 1971; Slamecka & Feveriski, 1983; Hasher & Zacks, 1979; Rabinovitz & Craik, 1986). Alternatively, students may read text carefully, but be unaware that a discrepancy exists between the two knowledge sources. Both adults and children are poor monitors of inconsistencies in text (e.g., Schneider & Pressley, 1989).
Helping Students Overcome Their Misconceptions

Recently, both researchers and educators have expressed interest in changing students' inaccurate prior beliefs, or what are otherwise known as misconceptions, alternative frameworks, or misunderstandings. It is important to help students alter their inaccurate beliefs given that misconceptions are pervasive, resistant to change under normal classroom instruction, and often impede acquisition of new content (e.g., Alvermann & Hynd, in press; Arnaudin & Mintzes, 1985; Bell, 1985; Brown & Clement, 1989; Champagne et al., 1982; Clement & Brown, 1984; Clough, Driver, & Wood-Robinson, 1987; Resnick, 1983; Roth, Anderson, & Smith, 1987). Even when students answer conventional tests and standardized assessments correctly, they may still possess beliefs that run counter to scientific thought (Arnaudin & Mintzes, 1985). Sometimes these inaccurate beliefs are revealed only after extensive interviewing, and thus go unnoticed by both educators and students. More often, students' misconceptions are not so subtle.

Unfortunately, the majority of research investigating whether students' inaccurate prior knowledge can be altered is comprised of either case studies (i.e., less than five subjects) or pilot projects (e.g., Brook, 1987; Brown & Clement, 1989; Driver, 1987; Hesse, 1987; Nussbaum & Novak, 1982; Scott, 1987; Roth, 1990), with few true
experimental investigations. However, there are three techniques that enjoy some empirical support and appear to be especially promising in changing students' misconceptions: (1) Refutation Text and Augmented Activation, (2) Conceptual Conflict and Accommodation, and (3) Anchoring and Bridging Analogies.

**Refutation Text and Augmented Activation**

Alvermann and her colleagues (e.g., Alvermann & Hague, 1989; Alvermann & Hynd, in press; Hynd & Alvermann, 1986; 1987) investigated whether specially designed text that refutes students' misconceptions (hereafter called refutation text) could help learners acquire scientifically accepted concepts.

Specifically, the refutation text designed by Alvermann and her associates addresses two opposing viewpoints about projectile motion: the scientifically accepted Newtonian Theory and the common misconception Impetus Theory. The refutation text used by these researchers provides support for Newton's theory while discounting Impetus theory. For example, consider the following excerpts from the refutation passage used by Hynd and Alvermann (1986):

A central point to be made is that the medieval impetus theory is incompatible with Newtonian mechanics in several fundamental ways....To get a sense of some of the motion studies mentioned, imagine the following situation. A person is holding a stone at shoulder height while walking forward at a brisk pace. What will happen when the person drops the stone? What kind of path will the stone follow as it falls? Many
people whom this problem is presented answer that the
stone will drop straight down, striking the ground
directly under the point where it was dropped. A
few people are even convinced that the falling stone
will travel backward and land behind the point of
its release. In reality, the stone will move forward
as it falls, landing a few feet ahead of the release
point. Newtonian mechanics explains that when the
stone is dropped, it continues to move forward at
the same speed as the walking person, because
(ignoring air resistance) no force is acting to
change its horizontal velocity.

Contrary to refutation text, traditional text describes
Newton's theory without alluding to Impetus Theory:

We certainly learn from our experiences. From
repeated exposures to particular events, we learn
to induce principles which guide our expectations
for future events....Newtonian mechanics can also
be used to predict what path a stone will follow
when it is dropped from shoulder height by a
person walking forward at a brisk pace. Assuming
no air resistance, the stone will move forwards
it falls to the ground, coming to rest a few feet
ahead of the point at which it was released. That
is, the stone continues to move forward at the
same speed as the person who is walking. Why?
Because no force is acting upon it to change its
horizontal velocity. Of course, as the stone
falls forward it also moves downward at a steadily
increasing speed. The forward and downward
motions result in a path that closely approximates
a parabola.

University students' understanding of projectile
motion was compared after reading either refutation or
traditional text. Approximately two thirds of the
students reading either text were instructed to activate
prior knowledge before reading, whereas the remaining
students were given nonactivation instructions. The
activation instructions were supplemented for some
students. Students assigned to augmented activation
condition were told that some ideas held by some people were different than the scientifically accepted ideas described in the text, and that they should pay special attention to text ideas that differed from their own.

Alvermann and her colleagues failed to find consistent learning gains following the reading of refutation text relative to reading traditional text. Superior retention for Newtonian theory was found in two investigations with developmental studies students (i.e., students who enter university with less than average high school grades, and/or low SAT scores; Alvermann & Hague, 1989; Hynd & Alvermann, 1986). However, in a series of other studies, university students of average ability failed to demonstrate substantial learning gains following the reading of refutation text (Alvermann & Hynd, 1987; Alvermann & Hynd, in press). The authors state that one possibility why refutation text aids poorer readers but not better ones, is that less competent readers may be less confident in their background knowledge and may be more willing to let refutation text dissuade them of their prior beliefs (Alvermann & Hynd, in press).

Regardless of text type, there were two consistent effects of activation. First, students who participated in the nonactivation group retained more text information than did activators -- that is, students assigned to the activation only group allowed their naive conceptions
about projectile motion to override information presented in the text (Hynd & Alvermann, 1987). This finding replicates earlier work by Alvermann et al. (1985), Lipson (1982), and Smith et al. (1984). More interestingly, students given augmented activation instructions retained more text information than students assigned to either the nonactivation or activation only conditions (Alvermann & Hynd, in press). The combination of telling students that inconsistencies may exist between their beliefs and scientific theory and then having them activate prior knowledge that was not consistent with text, may have created a state of conflict between the two cognitions so great that they abandoned their misconceptions. Another possibility, is that the warning of possible incongruities was sufficient to enhance learning. The warning may have increased students' attention to discrepancies between their own knowledge and text information. It remains to be determined whether giving students augmented directions without having them activate prior knowledge facilitates learning. The effects of both refuted text and augmented instruction also need to be determined for younger students (i.e., primary and secondary school children).

Conceptual Conflict and Accommodation

Nussbaum and Novick (1982) demonstrated some success changing grades 6, 7, and 8 students' faulty beliefs about particle theory of gases by using conceptual conflict and
accommodation. Many high school students, and even university students, harbor incorrect beliefs about particles (e.g., Novick & Nussbaum, 1978; 1981; Lee, Eichinger, Anderson, Berkheimer, Blakeslee; 1989). For example, many students believe that various substances like air, bacteria, and oxygen exist between gas particles, thus retaining the misconception that matter is continuous when in fact only empty space exists between gas particles.

The conceptual conflict approach designed by Nussbaum and Novick is comprised of three components: (1) an exposing event that requires students to acknowledge and rationalize their existing beliefs, (2) a discrepant event that causes conflict between existing beliefs and an observable phenomenon that they cannot explain and, (3) supporting students' search for, and elaboration of, the scientifically accepted concept. Nussbaum and Novick and others (e.g., Hewson, & Hewson, 1982; Posner, Strike, Hewson, & Gertzog, 1982) believe that learning involves the processes of assimilation (incorporating novel information into existing knowledge) and accommodation (restructuring and reorganizing existing knowledge based on novel information). Of the two, accommodation is the more radical and difficult to induce. Unfortunately, when a student possesses a misconception, accommodation is often necessary in order for the student to accept the
scientific concept (e.g., Roth, 1990). Two important conditions must be fulfilled before accommodation is likely to occur: (1) the learner must express some dissatisfaction with his/her existing beliefs and, (2) the learner must be willing to reduce conflict between the two cognitions. By explicitly creating conceptual conflict in the classroom, Nussbaum and Novick believe that students will be more aware of their existing misconceptions, and therefore, more motivated to learn science concepts.

To help primary school children understand the particle theory of gases, students were shown a demonstration in which air was sucked from a flask with a hand pump. In order for students to become familiar with their existing beliefs about particles, the children were asked to draw and explain pictures of the flask before and after the air was removed. The instructor then selected several of the students' models, as well as the scientifically accepted empty space model, for subsequent discussion.

After students had become familiar with their own beliefs, a discrepant event was introduced: the compression of equivalent amounts of air and water in syringes. Students were asked to reflect why it was possible to compress the air but not the water -- what special properties do gases have that liquids and solids do not? Students tried to demonstrate how their own
models could explain the compressibility of air. The instructor's task was to help students realize that, despite the strangeness of the idea, the empty space theory was the only model that could explain both the evacuation of air from the the flask and the compressibility of air in the syringe.

Unfortunately, the conceptual conflict-plus-accommodation approach adopted by Nussbaum and Novick has not been formally evaluated. Rather, program success is based on the large number of students who accept the scientific model at the end of the class sessions, and on the enthusiastic reports of instructors who have used conceptual conflict-plus-accommodation lessons. Although these reports encourage future research, they are not sufficient to warrant the conclusion that the program is effective (e.g., Pressley, Woloshyn, Lysynchuk, Martin, Wood, & Willoughby, 1990). At the very least, learning gains following participation in the conceptual conflict plus accommodation approach need to be evaluated relative to learning gains following didactic instruction.

**Anchoring and Bridging Analogies**

Another approach used to change students' misconceptions is analogy. An analogy defines similarities between concepts that are otherwise dissimilar. A good analogy helps learners relate novel information to a familiar concept. For example, a
geography teacher could explain the concept of a glacier by drawing an analogy to a river of ice, or an English teacher could explain the concept of a hierarchical outline by drawing an analogy to a tree and its branches (Glynn, 1988). Presumably this process makes the novel information more meaningful, and thus, more memorable. Clement and his colleagues (e.g., Brown, & Clement, 1989; Clement, & Brown, 1984; Clement, Brown, Camp, Kudukey, Minstrzell, Palmer, Schultz, Schimabukuro, Steinberg, & Veneman, 1987; Clement, Brown, & Zietsman, 1989) advocate the use of analogies when helping students abandon misconceptions and adopt scientific concepts.

Students often hold contradictory ideas, such that in one situation students' beliefs are consistent with scientific knowledge, but in another, they are incompatible. For instance, 76% of interviewed high school students responded that a table does not push up (i.e., force) on a resting book. However, the majority of these same students believed that a spring being pushed down by a hand, does push up on the hand (Clement et al., 1987). To scientists, the students' responses are inconsistent because the two situations are equivalent.

Clement labeled the spring/hand example an "anchoring conception." By definition, an anchoring conception is an intuitive belief (i.e., one that is self-evaluated and not tested by an appeal to authority) held by students that is
in rough agreement with scientific theory (Clement et al., 1989). Clement proposed that instructors should use these anchoring conceptions as a starting point for instruction. Specifically, the instructor should help students realize that the anchoring concept (i.e., spring/hand) is analogous to the misunderstood concept (i.e., table/book).

Unfortunately, direct comparison of the misconception and anchoring conception is often insufficient for students to acknowledge that both situations are analogous. Instead, "bridging examples" are required to help students make this connection. Bridging examples share features that are similar to the anchoring conception as well as to the misconception. For example, a bridging analogy for the table and spring comparison could be a book resting on a flexible board supported by two pillars (the flexible board has characteristics of both a table and a spring). The student may be led to believe that the board bends slightly (just as a spring does when pushed by a hand) by instructing him/her to imagine placing either sequentially thicker and thicker books on it, or to imagine placing a book on a sequentially thinner and thinner table. Hopefully, through the use of successive bridges, students will be more willing to accept the anchoring example and misconception as similar (Carnine, 1980).

Although there are many documentations of case
studies where students have accepted scientific theory following instructions to use anchoring and bridging analogies, there appears to be only one experimental investigation of this approach (i.e., Clement et al., 1987). In this study, the authors used the described analogy technique to teach four high school physics classes about static objects (i.e., the table-spring analogy), frictional forces, and Newton's third law of collisions, whereas regular classroom instructors used traditional methods to teach the same content at another school. Pretest and posttest performance measures (multiple choice questions tapping common misconceptions) were used to assess learning gains following instruction. Two months following training, Clement found that pretest-posttest scores were, on average, two standard deviations greater for students taught via analogy than for students taught using traditional methods. Although there are methodological shortcomings with the Clement et al. study (e.g., nonrandom assignment to study conditions, differences in instructor training), the findings suggest that anchoring and bridging analogies can help students create associations between existing knowledge and novel information even when students' initial intuitions about the target concepts are incorrect.

All three approaches (refutation text plus augmented activation, conceptual conflict and accommodation, and
anchoring and bridging analogies) appear to be promising techniques in helping students overcome misconceptions. Additional research needs to be carried out including measuring learning gains relative to didactic control groups and over extended time intervals. Other important questions include whether these techniques can be used with all age groups and school curricula.

An important limitation to these approaches, with the possible exception of augmented activation, is that they require substantial resources from instructors, both in the planning of program materials and in the supervision of strategy use. For example, when using the conceptual conflict-plus-accommodation approach, instructors need to seek out appropriate exposing events and invest large amounts of time helping children activate their existing conceptions, explaining the discrepant event, and helping students accept the scientific concept. Similarly, Clement acknowledges that a great deal of care and effort are needed when searching for anchoring and bridging analogies. Pilot testing has revealed that some analogies that appear intuitive to instructors do not appear so to students. Finally, the revision of text is certainly time consuming and tedious.

Alternative strategies that can help students overcome their misconceptions need to be investigated, especially those that require minimum resources from instructors.
Greater attention should be directed to strategies that are already known to enhance acquisition of novel information. For example, elaborative interrogation is a question-answering strategy that has been demonstrated to enhance fact acquisition for both adults and children (e.g., Pressley, McDaniel, Turnure, Wood, & Ahmad, 1987; Pressley, Symons, McDaniel, Snyder, & Turnure, 1988; Woloshyn, Willoughby, Wood, & Pressley, 1990; Wood, et al., 1990).

**Elaborative Interrogation**

Elaborative interrogation is a learning adjunct that requires subjects to generate answers to why questions when given nonelaborated factual materials. For example, given the statement "British Columbia is the province with the highest percentage of its population in unions," students would be asked to answer why this is true of British Columbia and not another Canadian province. Students would be instructed to reflect on their knowledge of Canadian history, geography, economics, etc., to help them answer the why question. In other words, elaborative interrogation requires students to use their prior knowledge to generate inferences and elaborations that support the presented facts.

Pressley and his colleagues (Pressley et al., 1987) found that instructions to use elaborative interrogation enhanced both intentional and incidental learning. When
adult subjects were asked to generate answers to why questions about different types of men (e.g., fat, bald, tall), they learned more about these men than did subjects who were given elaborated statements that made obvious the significance of the stated facts (i.e., precisely elaborated statements; Stein & Bransford 1979). For example, students who were asked to explain why, "The tall man bought crackers," retained that information better than did subjects who read the precisely elaborated statement, "The tall man bought crackers which were on the top shelf." Presumably the sentence extension," which were on the top shelf" makes clear why a tall man would buy the crackers. Subjects who attempted to answer why questions also retained more information than subjects who read nonelaborated sentences, "The tall man bought the crackers."

Findings from subsequent studies have confirmed that elaborative interrogation is a powerful learning adjunct — memory performances of subjects assigned to elaborative-interrogation conditions were consistently superior to memory performances of subjects assigned to reading-control conditions (e.g., Pressley et al., 1988; Woloshyn et al., 1990). This is an especially impressive finding given that the reading-to-understand control groups used by Pressley and his colleagues were stringent ones, with subjects instructed to process the to-be-learned
statements for meaning and to engage in the reading task for the entire time that the materials were presented. Learning gains following elaborative interrogation were greater than those following the use of at least one other elaboration strategy (i.e., self-reference), and just as potent as those produced by instructions to create interactive mental images — a strategy well known to enhance retention for paired associates, sentences, and prose passages for both adults and children (e.g., Anderson & Kulhavy, 1972; Anderson & Hidde, 1971; Denis, 1984; Giesen & Peeck, 1984; Guttman, Levin, & Pressley, 1977; Paivio, 1971; Paivio & Yuille, 1967, Rasco, Tennyson, & Boutwell, 1975).

Of particular relevance here, even young children can use the elaborative-interrogation strategy effectively (Wood et al., 1990). Wood and her colleagues had students in grades 4 through 8 learn factual statements about arbitrary man statements (e.g., The hungry man got into the car). Intentional learning gains following instructions to use elaborative-interrogation were contrasted with gains following the use of other strategies, including experimenter-provided precise elaborations, imagery, and reading-for-understanding. Specifically, students assigned to the reading-control group were instructed to read each sentence aloud at a rate that allowed them to understand what facts were true.
Children in the experimenter-provided explanatory elaboration condition were informed that the part of the sentence that was not underlined (i.e., the precise elaboration) would help them remember the underlined part of the sentence. Children in the imagery conditions were instructed to create an interactive image depicting the sentence events. Elaborative-interrogation subjects were asked to generate an answer that would explain why each statement was true.

Consistent with findings in the adult literature, performances in the elaborative-interrogation and imagery conditions were superior to performance in a reading-to-understand control condition. For older children (i.e., 11 1/2 to 14 years of age) elaborative interrogation was also more effective than provision of precise elaborations.

In a follow-up study (Wood et al., 1989, Experiment 2), students in grades 4 through 8 were asked to learn facts about animals indigenous to Canada. A series of six factual statements was presented for each of nine animals (i.e., physical living environment, diet, sleep habits, major source of predation, preferred habitat). Students were randomly assigned to one of two intentional control groups (no exposure control, reading-to-understand control) or four intentional learning conditions (experimenter-provided explanatory elaborations, experimenter-provided explanatory elaborations with
imagery instructions, imagery, and elaborative-interrogation). Children assigned to the no-exposure control group completed the cued recall memory test without studying the critical text materials. In all other conditions, participants were given processing instructions similar to those used in Experiment 1.

All experimental groups plus the reading-to-understand control group retained more sentence information than did the no-exposure control group, eliminating the possibility that performance scores could be attributed to familiarity with the study materials. Subjects assigned to the elaborative-interrogation and imagery conditions recalled more animal facts than did subjects assigned to the experimenter-provided explanatory condition. No other recall differences were significant.

That self-generated elaborations afford better retention for stated facts than experimenter-provided elaborations is consistent with other demonstrations that learning is better when study includes active generation of target materials (e.g., Jacoby, 1978; Slamecka & Feveriski, 1983). One reason for learning gains is that self-generated elaborations are more likely to be consistent with the learner's prior knowledge than are experimenter-provided elaborations.

An interesting aspect of Pressley and his colleagues' data was that, for adults, even attempting an answer
facilitated recall relative to when subjects read text. Recall was enhanced even when students were unsuccessful in generating responses to why questions. In fact, quality of elaboration had little effect on retention, with only a slight advantage for precise or adequate responses (i.e., responses where subjects used prior knowledge: Pressley et al., 1987; Woloshyn et al., 1990). However, for younger children, search alone did not guarantee enhanced recall -- that is, simply trying to answer a why question did not always improve learning (Wood et al., 1990). Essentially, recall was facilitated for arbitrary statements where it was assumed that learners possessed a great deal of prior knowledge. Recall was not facilitated for facts about which students had relatively little prior knowledge.

There are several possibilities why merely attempting to answer why questions would enhance memory for adults but not necessarily for children. For adults, attempting to generate an answer may promote a distinct encoding of the factual information (Slamecka & Feveriski, 1983; Slamecka & Graf, 1978), perhaps because the learners possess a number of associations to the fact -- ones that are searched in the attempt to produce an answer to the why question (Anderson & Reder, 1979). With children, however, unsuccessful searches probably reflect occasions when there is very little prior knowledge. Hence, few
relevant associations could be activated when attempting to find the answer to the why question and, since few mediating links are activated, there would be little facilitation of learning. Fortunately, the instances of response failures were low, with both adults and children generating adequate responses for the majority of items.
Experiment 1

The primary purpose of the first experiment was to determine whether the elaborative-interrogation study strategy would help elementary-school students acquire science facts. Specifically, the study was intended to replicate Wood et al.'s, (1990) finding that school-aged children benefit from using elaborative interrogation when studying novel factual information. More importantly, the study also investigated whether elaborative interrogation could help students acquire science facts about which they possessed inaccurate beliefs (i.e., misconceptions). Elaborative interrogation was believed to be a particularly well suited strategy for helping students overcome their misconceptions because it prompts learners to use their prior knowledge to support factual information as presented.

Another purpose of the study was to assess whether reading either refutation text or inverted refutation text (i.e., text where the science fact is presented first and followed by refutation of a common misconception (e.g., The light of the sun is made of every different colour including purple and violet, although some people think that it is only red and orange) would enhance fact acquisition. Alvermann and her colleagues (e.g., Alvermann & Hague, 1989; Alvermann & Hynd, 1986; 1987)
found that less competent university students benefited from reading text that supported science concepts while refuting common misconceptions (i.e., refutation text). Alvermann et al., suggested that these readers were not as committed to their inaccurate beliefs as were university students of average ability, and thus, were more willing to accept the scientifically accepted concepts. Young readers, who have less reading experience and general world knowledge than older students, might also be less committed to their inaccurate beliefs and benefit from reading either refutation text or inverted refutation text relative to reading traditional text. Alternatively, reading either form of refutation text might prompt students to retrieve both accurate and inaccurate information at test, thereby increasing the likelihood that retention errors will be made (i.e., learners will need to make a decision between competing memories).

It was also not clear what effect reading either refutation text or inverted refutation text would have on learning if used in conjunction with elaborative interrogation. Perhaps the combination of refutation text and question-answering would increase students' efforts to find support for the science facts, which in turn, would enhance retention. Alternatively, presenting both scientifically accepted facts and misconceptions might divert students' attention away from the true facts, and
focus students' attention on the misconceptions.

Using intentional learning instructions, participating students were asked to process individually presented statements about several topics that were written in either traditional text, refutation text, or inverted refutation text. Half the presented statements were consistent with the learners' prior knowledge, whereas the remaining statements were inconsistent with their existing knowledge. The students were asked to perform one of two tasks: read the sentences aloud at a rate that allowed them to understand that each fact was true (reading-to-understand control condition) or answer aloud a "why" question about each sentence (elaborative-interrogation condition). In order to assess learning gains, students were asked to complete two measures of recall (free and cued recall) and two measures of recognition (immediate and 14-day delayed sentence selection questionnaires).

Method

Pilot Materials, Questionnaire Testing, and Test Item Selection

One hundred and eighty sentence pairs consisting of an equal number of true statements (listed in Appendix A) and false statements (listed in Appendix B) were constructed for piloting. These statements were generated from information contained in primary and elementary
school texts and published research. True statements were collected first. Sentences were selected because they were believed to contain information that was inconsistent with students' prior knowledge. In total, information about fourteen topics was collected: (1) sun (Alvermann et al., 1985; Gough & Flanagan, 1980; Tamir, Gal-Choppin, & Nussinovitz, 1981), (2) rattlesnakes (Alvermann et al., 1985), (3) water (Gough & Flanagan, 1980), (4) three states of matter (Erickson, 1979; Doran, 1972; Lee et al., 1989; O'Flanagan, Donovan, & O'Keefe, 1981), (5) plants (Adeniyi, 1985; Bell, 1985; Gough & Flanagan, 1980; Tamir et al., 1981), (6) cells (Barrass, 1984; Gough & Flanagan, 1980), (7) earthworms (Gough & Flanagan, 1980), (8) planets (Gough & Flanagan, 1980), (9) blood (Arnaudin & Mintzes, 1985; Barrass, 1984), (10) animals (Adeniyi, 1985; Bell, 1981; Gough & Flanagan, 1980), (11) genetics (Clough & Wood-Robinson, 1985; Deadman & Kelly, 1978; Kargbo, Hobbs, & Erickson, 1980), (12) frogs (Gough & Flanagan, 1980), (13) rocks (Gough & Flanagan, 1980), and (14) AIDS (DiClemente, Pies, Stoller, Straits, Olivia, Haskin, Rutherford, 1989; DiClemente, Zorn, & Temoshok, 1986, 1987; Price, Desmond, & Kukulka, 1985).

For each true statement, an opposing false statement was created. This was done by negating the true statement and/or substituting a known misconception about the sentence topic. The sentence format and wording of the
false statements resembled the true statements as closely as possible. The average length of the statements was 11 words (range = 9 to 14 words).

Although readability formulas have been criticized as incapable of providing insights about the mechanisms involved in reading, language, or learning, and as being unable to define what makes a passage difficult to read, they can provide some indication whether surface features of a text, such as sentence length and vocabulary, are age appropriate (Davison, 1984). The Fry readability formula (Fry, 1968; 1977), which measures readability via sentence length and number of syllables per word, was used as a rough indicator of reading level. The overall readability of the statements was at a grade 6 reading level, with topic units ranging from grade 5 to grade 7 in reading difficulty. Two primary school instructors were also asked to review the statements and make comments about the readability of the statements and the appropriateness of the content for elementary school students.

These statements were used to develop 12, 15-item questionnaires. The questionnaires were similar in format to the one used by Lipson (1982), with an individual test item consisting of one correct and one incorrect statement. Below each sentence pair the phrase "The correct statement is number ___?" and the words "100% SURE", "50% SURE", and "100% UNSURE" were written. Two
blank lines followed.

Sixty grade 7 and 8 students and 36 grade 5 and 6 students were recruited from local boys and girls organizations (i.e., Memorial Boys and Girls Club, Girl Guides, and Path Finders). These children were asked to complete 1 of the 12 short questionnaires. The children were instructed to read each sentence pair and to select the statement that they believed was true. They were then asked to circle their response certainty. It was explained that they should be as honest and as accurate as possible when they were completing these ratings. Students were also asked to make comments about the readability of the questionnaires and the familiarity of the content. The children were able to complete the questionnaires in 15 minutes or less.

Based on these students’ responses, 4, 35-item sentence selection questionnaires were developed (listed in Appendix C). Information that was generally well known (e.g., AIDS) and information about which students had no relevant prior knowledge (e.g., genetics) was removed. For some topics (e.g., plants) additional statements were created.

**Testing**

Forty students in each of grades 6, 7, and 8, and 28 students in grade 5, were recruited to complete the 4, 35-item questionnaires. The students attended one of two
elementary schools in the Hamilton-Wentworth area. Students were tested as a group during science in their regular classrooms. Eight to 10 students in each grade were randomly assigned to complete one of the four questionnaires. The students were told that their help was being solicited by researchers who were interested in investigating what type of information was familiar to children in their particular grade. Students were instructed to complete each test question to the best of their abilities.

Specifically, the students were instructed to decide which of the statement pairs they believed was true and to indicate that statement as true in the appropriate space below each sentence pair. Students were told to make their best guess when they were uncertain of the correct response, and that it was very important that they attempted every question. However, the students were allowed to skip test items about unfamiliar content (i.e., topics for which they believed they had no relevant knowledge).

Students were also instructed to rate their response certainty for each answer by circling one of the three options (i.e., 100% SURE, 50% SURE, 100% UNSURE). The experimenter explained that students should circle 100% SURE when they were very confident that their answers were correct, 50% SURE when they were fairly sure that their
answers were correct but had some concerns about accuracy, and 100% UNSURE when they were guessing. Finally, students were asked to write a brief explanation about why they believed the statement that they selected was true (e.g., they learned the information at school, they had witnessed that particular event). Students were not required to give explanations for items that they circle 100% UNSURE. When students could provide a source for their knowledge, they tended to rely on their everyday experiences (43%), classes (33%), media (16%), and conversations with peers and elders (8%).

The students were told to raise their hand if they encountered a word or sentence that they did not understand while reading and that the experimenter would clarify its meaning. Students' questions were recorded for final editing of test materials. The questionnaires were also made available to the classroom teachers for commentary. Most students were able to complete the questionnaires in 45 minutes or less.

**Test Item Selection**

Thirty-two true factual statements were selected for experimental materials. The statements were about four content areas (i.e., solar system, circulatory system, plants, and animals), with eight sentences for each topic. Half of the statements were about scientific content that was inconsistent with students' prior knowledge
(misconceptions), whereas the remaining statements were about novel facts that were consistent with their knowledge.

Specifically, scientific statements that were inconsistent with students' prior knowledge were questionnaire items for which at least 50% of the children in each grade (range = 50% to 100%, mean = 68%) selected the false statement as correct with either 50% or 100% certainty. Novel statements were selected from untaught portions of science texts. Class instructors verified that the selected facts were novel but about familiar concepts.

Subjects

The participants were 60 elementary school children (16 grade 6 males and 14 grade 6 females, $X = 11.4$ years old, $SD = .56$; 17 grade 7 males and 13 grade 7 females, $X = 12.40$ years old, $SD = .56$) attending the two public schools that provided the subjects who completed the sentence selection questionnaires. Twenty-one days separated the interval between piloting for test materials and the first experimental session. Fifteen students in grade 6 and 15 students in grade 7 were randomly assigned to either the elaborative-interrogation or reading-control conditions so that 30 students participated in each group. An equal proportion of students from the two schools was assigned to each test condition, with approximately an
equal number of males and females assigned to each condition. All students were proficient English speakers. The students were tested individually and in a quiet setting. The experimental session lasted between 45-60 minutes.

Materials

Two sets of to-be-learned materials were constructed (listed in Appendix D). Each set contained 36 white, 12.5 cm by 19.5 cm cards, with one factual statement printed in upper case per card. An audio recording of the two sets of factual statements was made by an adult male. The tape was used to help ensure that all subjects processed the to-be-learned materials at least once. Prior research conducted with both children (e.g., Wood, et al., 1990) and adults (e.g., Woloshyn et al., 1990) indicated that 20 seconds would be sufficient time to complete the required study tasks.

Across both sets of test materials, each of the to-be-learned facts was written in one of the three text types: traditional, refutation, and inverted refutation. Specifically, statements written in traditional text contained only the science fact (e.g., Oxygen and air are not the same). Statements written in either type of refutation text contained both the true fact and a common misconception. Both types of refutation text were written in a manner that supported the science fact and negated
the misconception. When refutation text was used, the misconception was presented first and the science fact followed (e.g., Although some people think that oxygen and air are the same, they are not the same). When inverted refutation text was used, the scientifically accepted fact was presented first and the misconception followed (e.g., Oxygen and air are not the same, although some people think that they are the same).

One practice sentence set, consisting of four animal statements, was presented at the beginning of the study phase. Two of the statements contained information that was consistent with students' prior knowledge, whereas the other two statements contained information that was inconsistent with the students' prior knowledge. Two of the statements (one about a misconception and the other about a novel fact) were written in traditional text, one statement was written in refutation text, and the remaining statement was written in inverted refutation text. The practice sentences were used to help ensure that students understood and followed the orienting task instructions. These sentences were not included in the final analysis of the data.

The remaining 32 sentences consisted of factual statements about four different topics. A sentence set consisting of eight statements was presented for each area. Half the statements (eight addressing
misconceptions and eight novel facts) were written using traditional text. The remaining statements were written using refutation text (four facts about misconceptions and four facts about novel information) and inverted refutation text (four facts about misconceptions and four facts about novel information).

Two random orders of sentence presentation were developed. Statements that appeared in traditional text in the first study order were presented in one of two refutation texts in the second study order and vice versa. Students were randomly assigned to one of the two study orders.

An orienting instruction was typed in upper case on a stand-up cue card that was placed beside each subject. The prompt for the reading-to-understand control group was "Read the sentence out loud at a rate that lets you understand that the fact is true." The prompt used for the elaborative-interrogation condition was "Why is that fact true?" A portable Sony tape recorder and clip microphone were used to record subjects' study responses. The tape recorder was placed in full view of each child.

Procedure

The experimental session consisted of six phases: instructions, study, free and cued recall, posttest interview, immediate sentence selection questionnaire, and 14-day delayed sentence selection questionnaire.
Instructions

The students were told that they would see individual sentences stating true facts about four different topics. Special care was taken to tell the students that the presented statements were true facts. The students were also told about, and provided examples of, the three different types of text. Students were informed that the nature of the task that they would be asked to perform would remain constant regardless of the type of text, and that they should pay special attention to the scientifically accepted facts. The subjects were also told that several statements about the same topic would be presented one after the other. It was believed that the presented information appeared arbitrary to the students since no explanation was given to clarify the relationships between the stated facts and the topics being discussed.

In order to enhance subjects' fact acquisition (floor effects are often obtained on memory measures where incidental instructions are used with young students), and increase the ecological relevance of the task (presumably students know that they will be tested on information that they study in an educational context), an intentional learning paradigm was used. Thus, all students were informed that they would be asked about the presented information. The specific instructions that were given to
students, however, varied as a function of experimental condition.

Reading-to-understand control subjects were asked to read each statement out loud, and in a continuous manner for the entire time that the statement was presented. Specifically, reading control subjects were directed as follows:

I am going to show you some true statements about several different topics. Even though some of the facts may seem surprising to you, they are indeed true. Your task is to read each sentence out loud at a rate that allows you to understand that the presented fact is true. Read the sentence out loud over and over again until you hear the sound of a bicycle bell and a new statement is presented. It is very important that you read each sentence out loud at a rate that allows you to understand that the stated fact is true. If you cannot understand the sentence, you are probably reading the information too fast and need to slow down. Make sure to read very carefully, as I am going to ask you about the sentence information later. Make sure that you also speak loudly as I am going to tape record your reading. Do you have any questions? Okay, lets do some practice items first.

Subjects assigned to the elaborative-interrogation condition were instructed to read each statement silently, but to answer out loud an associated "why" question.

These students were given the following instructions:

I am going to show you some true statements about several different topics. Even though the facts may seem surprising to you, they are indeed true. Your task is to answer out loud a why question about each sentence. The question will always be the same and is: Why is that fact true? It is very important that you try and answer why each fact is true. In order to help you come up with an answer,
you might want to think about information that your teachers have told you in class, information that you have read about, and your everyday experiences. It is very important that you attempt to answer each question so that you explain why the presented fact is true. Even if you are not sure that your answer is correct, make your best possible attempt. Because I am only going to give you a brief time to read each sentence and answer the why question, you may not be able to generate an answer for every sentence. Do not be upset about this. Just try your best to answer each question. When you hear the sound of a bicycle bell you must go on to the next sentence, even if you have not completed your answer. Make sure to try and answer every question as I am going to ask you about the sentence information later. Make sure that you also speak loudly as I am going to tape record your answers. Do you have any questions?

Okay, let's do some practice items first.

The four practice sentences were presented in a constant order at the beginning of the study session. Subjects were required to demonstrate how they would carry out the required processing for these materials (i.e., read the statements out loud, answer out loud the why question). After each practice statement, subjects were given feedback about their responses and an example of an appropriate response. For instance, given the practice statement "Although some people think that the spider is an insect, the spider is not an insect", reading-control subjects were given feedback about their reading speed and clarity. Elaborative-interrogation subjects were given commentary about their particular answer and were informed that one way spiders and insects differ is that the former
have eight legs, whereas the latter have six.

**Study**

The 32 to-be-learned statements were presented individually to the subjects at 20 seconds per card intervals. The study instructions appropriate to each condition were reiterated when appropriate.

**Free Recall and Cued Recall Memory Tests**

Following the study phase, subjects participated in free and cued recall memory tests. For free recall, they were instructed to recall as much of the presented information as possible given only the titles of the four content areas. Topic titles were presented in a random order to each subject with the exception that the last topic studied was never the first tested, thus minimizing short-term memory effects. All subjects were instructed to remember as many facts as possible and to make their best guess when they were unsure of a correct response. They were also informed that one way to enhance recall was to reflect on the way information was originally processed (cf., encoding specificity; Tulving & Thomson, 1973). Specifically, reading-control subjects were told that reflecting on how information was read may help them recall more facts. Elaborative-interrogation subjects were told that trying to remember their answer to the why question might help them remember the study statements.

Subjects were given unlimited time to recall text
information with responses tape recorded for subsequent analyses. They were instructed to signal the experimenter when they were unable to recall any more information about the particular topic being discussed. At this point, the experimenter provided them with prompts about passage content that was not recalled spontaneously (i.e., cued recall memory test). Specifically, the experimenter provided the subjects with a prompt that contained two critical pieces of sentence information. For example, "Can you tell me about the oxygen and air?" After reviewing all the critical information about the topic in question, the experimenter provided the subjects with another title for free recall, and if necessary, cued recall prompts until all four topics were tested.

**Posttest Interview**

After completion of the cued recall memory test, a posttest interview was administered. The purpose of the posttest interview was to assess whether the subjects followed the instructions specified for each study condition, and to assess how difficult subjects found their assigned tasks. Students were shown three study statements (one written in each type of text) and were asked to elaborate on what they were thinking when they read the sentences for the first time. It was stressed that they should be as accurate as possible when describing their thought processes and that they should be
careful to describe what they were actually thinking. In addition, the subjects were asked to rate on a scale from one (very easy) to ten (very hard) how difficult they found the assigned task for each of the four study topics. That is, reading-control subjects were asked to rate how hard it was to read the sentences out loud at a rate that allowed them to understand what facts were true for each content area. Elaborative-interrogation subjects were asked to rate how difficult it was to answer the "why" question for each topic. Finally, subjects were asked to rate how difficult they found the three types of text to read and understand (i.e., 1 = very easy, 10 = very hard).

Immediate and Delayed Sentence Selection Questionnaires

The experimental session ended with students completing a sentence selection questionnaire about content that corresponded to the critical test items. The questionnaire was similar in format to the one administered during piloting of materials except that students were not required to provide the knowledge source for their selections (questionnaire is listed in Appendix E). After the students had been instructed how to complete the questionnaire (i.e., that they should select the statement they believed was true and circle their response certainty), they were seated in a quiet room adjacent to the testing area. The students were told that
they should reflect on the information that they had just studied when completing the questionnaire. Students were given unlimited time to complete the questionnaire.

The students were asked to complete the sentence selection questionnaire for a second time (i.e., delayed memory test) approximately 14 days after participating in the experimental session. The delayed questionnaire was administered by the students' homeroom teacher and was completed during class time. The students were given similar instructions regarding the completion of the questionnaire except that no explicit reference was made about information presented at study.

Results

Format

The primary analyses involved the recall (free and cued recall) and recognition (immediate and 14-day sentence selection questionnaires) data. Subjects could receive a maximum score of 32 points on each of these tests (16 points for facts addressing misconceptions; 16 points for novel facts). Two independent raters analyzed the free and cued recall responses with respect to whether they corresponded with factual information presented at study. A response was considered correct if it was synonymous with the scientifically accepted fact. The raters agreed on 97% of the free recall and 98% of the cued recall classifications. Disagreements between the
two raters were resolved by discussion.

The learning gains due to strategy were reported separately from those due to type of fact and type of text, as the primary objective of this experiment was to determine whether elaborative interrogation would facilitate acquisition of science information. In order to ensure that any differences between subjects' cued recall scores were not confounded by free recall responses, these scores were analyzed both with and without free recall. Essentially, subjects' scores on the free recall task were carried over to the cued recall task for the former analysis, whereas subjects' cued recall scores were based on the number of items that were not spontaneously generated during free recall for the latter.

To further determine the potency of the elaborative interrogation strategy, subjects' certainty ratings (i.e., 100% Sure, 50% Sure, 100% Unsure) were analyzed for both correct and incorrect recognition responses. Ideally, use of the elaborative interrogation strategy would not only facilitate successful recognition, but would also enhance students' confidence for their correct decisions. Finally, errors generated during free and cued recall were analyzed to ensure that any elaborative interrogation learning gains were not artifacts of more retrieval attempts.

Secondary analyses included determining the
relationship between students' elaborative-interrogation study responses and subsequent learning. Specifically, conditional probabilities were carried out for study items where students provided answers that a) used prior knowledge to explain why the facts were true, b) did not use prior knowledge to make this relationship clearer and, c) response 'failures. All students' responses to the posttest interview were also analyzed.

Learning Gains Due to Strategy

Subjects raw scores were converted into proportion correct (to allow for meaningful comparisons across the three text types) with means and standard deviations listed for each dependent measure in Table 1. For each of the dependent measures, a 2 (strategy) by 2 (fact) by 3

-----------------------------------

Insert Table 1 about here

-----------------------------------

(text) Anova was carried out, with repeated measures on the last two variables. Tukey's HSD (honestly significant difference) test was used to determine significant group differences, inasmuch as this test allows for control of Type I comparisonwise error rate (Kirk, 1982).

For both free and cued recall, there were significant main effects for strategy (free recall F(1,58) = 26.54, p<.001; cued recall F(1,58) = 37.76, p<.001). Elaborative-interrogation subjects recalled more presented facts than did reading-control subjects (smaller q = 3.04,
Table 1

Proportion of Target Items Retained for Free Recall, Cued Recall, Immediate and Delayed Sentence Selection Tests as a Function of Fact and Text Type: Experiment 1

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<thead>
<tr>
<th>Condition</th>
<th>Misconceptions</th>
<th>Novel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
<td>R</td>
</tr>
<tr>
<td>Elaborative-Interrogation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>.333</td>
<td>.317</td>
</tr>
<tr>
<td>SD</td>
<td>.159</td>
<td>.262</td>
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<tr>
<td>Reading Control</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>.154</td>
<td>.203</td>
</tr>
<tr>
<td>SD</td>
<td>.156</td>
<td>.219</td>
</tr>
</tbody>
</table>

| Cued Recall       |     |     |     |     |     |     |
| Elaborative-Interrogation |     |     |     |     |     |     |
| X                 | .783| .775| .733| .729| .842| .817|
| SD                | .207| .273| .245| .189| .232| .270|
| Reading Control   |     |     |     |     |     |     |
| X                 | .471| .667| .533| .446| .583| .508|
| SD                | .227| .240| .284| .268| .296| .297|

*(table continues)*
<table>
<thead>
<tr>
<th>Condition</th>
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<th>Novel&lt;sup&gt;b&lt;/sup&gt;</th>
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</thead>
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<td>T&lt;sup&gt;C&lt;/sup&gt;</td>
<td>R&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cued Recall Without Free Recall</td>
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<th>Novel&lt;sup&gt;b&lt;/sup&gt;</th>
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<tr>
<td>$SD$</td>
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<td>.263</td>
</tr>
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</table>

**Note.** $n = 30$ for each condition.

<sup>a</sup> Facts addressing common misconceptions.

<sup>b</sup> Novel facts.

<sup>c</sup> Traditional text.

<sup>d</sup> Refutation text.

<sup>e</sup> Inverted refutation text.
The cued recall data were also analyzed independent of the subjects' free recall responses. Specifically, cued recall scores were transformed into proportions based on the number of test items not spontaneously generated during free recall. The same pattern of findings held: There was a main effect for strategy ($F(1,58) = 30.27$, $p < .001$), with elaborative-interrogation subjects recalling more factual information than reading-control subjects, $\eta = 3.15$, $p < .05$.

There were also significant main effects of strategy on both tests of recognition [immediate $F(1,58) = 18.50$, $p < .001$; 14-day $F(1,58) = 14.02$, $p < .001$]. Elaborative interrogation provided better recognition of science facts than did reading for understanding (smaller $\eta = 3.38$, $p < .01$).

Learning Gains Due to Text and Fact Types

For the free recall task, there was a significant main effect for text [$F(1,116) = 12.94$, $p < .001$] but not for fact [$F(1,58) = .16$, $p > .05$]. The text by fact interaction was also significant [$F(2,116) = 3.10$, $p < .05$], although the multisample circularity assumption was not tenable, indicating a positively biased $F$ test ($X^2 = .01$). The fact by text interaction was not significant when the Geisser-Greenhouse conservative $F$ and adjusted $F$ tests were used.

Reading refutation text enhanced recall for facts
relative to reading either traditional text ($q = 3.78$, $p<.01$) or inverted refutation text ($q = 4.67$, $p<.01$).

There were no recall differences between inverted refutation text and traditional text ($q = .89$, $p>.05$).

Analysis of the fact by text interaction indicated that the inverted refutation and refutation text advantage over traditional text was restricted to the acquisition of novel facts (smaller $q = 6.53$, $p<.01$). There were no differences between the three types of text for recall of facts that addressed common misconceptions (largest $q = 2.82$, $p>.05$).

For cued recall, there were significant main effects for text regardless of whether data were analyzed with or without the subjects' free recall responses ($F(2,116) = 7.78$, $p<.001$; $F(2,116) = 4.33$, $p<.01$ respectively). The main effect for fact was not significant (larger $F(1,58) = .53$, $p>.05$), nor were there any significant interactions.

Reading refutation text tended to enhance cued recall relative to reading traditional text (cutoff $q = 3.31$, $p<.05$; cued with free recall $q = 3.79$, cued without free recall $q = 2.95$). There were no significant differences between inverted refutation text and traditional text (larger $q = 1.40$, $p>.05$) or between inverted refutation text and refutation text (larger $q = 2.39$, $p>.05$).

Analysis of the immediate sentence selection
questionnaire indicated a main effect for fact \(F(1,58) = 28.46, p<.001\). Subjects were better able to recognize novel facts than facts that addressed misconceptions \(F = 4.00, p<.01\). There was a significant interaction between fact and text \(F(2,116) = 3.71, p<.05\). Reading refutation text enhanced recognition of facts for which students had pre-existing misconceptions relative to reading either traditional text \(F = 3.27, p<.05\) or inverted refutation text \(F = 4.98, p<.01\). There was no significant advantage associated with text type and the acquisition of novel facts \(F = .47, p>.05\).

There was also a significant interaction between strategy and text \(F(2,116) = 3.25, p<.05\). For reading-control subjects, refutation text enhanced recognition of science facts relative to traditional text \(F = 3.47, p<.05\) and inverted refutation text \(F = 4.67, p<.01\). There was no significant difference between traditional text and inverted text \(F = 1.21, p>.05\). There were also no significant differences between the three types of text for the elaborative-interrogation subjects \(F = .16, p>.05\).

These interactions should be interpreted cautiously as the multisample circularity assumption was not held \(X^2 = .01\) for the fact by text interaction and \(X^2 = .02\) for the strategy by text interaction. Both interaction \(F\) values failed to reach significance when the Geisser-
Greenhouse conservative F and adjusted F tests were used. For the 14-day sentence selection questionnaire, there were significant main effects for fact \(F(1,58) = 16.40, p < .001\), and text \(F(2,116) = 5.69, p < .005\). Students were better able to recognize novel study facts than facts addressing common misconceptions \((q = 3.16, p < .05)\). Reading refutation text enhanced recognition relative to reading inverted refutation text \((q = 3.06, p < .05)\). There were no performance differences between traditional text and refutation text or between traditional text and inverted refutation text \((\text{larger } q = 2.23, p > .05)\). There were no significant interactions.

**Certainty Responses for Sentence Selection Questionnaires**

The students' certainty ratings for the sentence selection questionnaires were also analyzed. Specifically, students' responses were classified as either correct/incorrect with 100% certainty, 50% certainty, or 100% uncertainty. Of primary interest were the interactions involving strategy, accuracy, and certainty (there could be no main effects for strategy given that the students provided answers to all the test items). A 2 (strategy) by 2 (accuracy) by 3 (certainty) Anova with repeated measures on the last two variables was carried out for both the immediate and 14-day delayed sentence selection questionnaires. Separate analysis were
run for facts addressing common misconceptions and novel facts. Accuracy plus certainty responses for the two types of facts are listed in Table 2 as a function of experimental condition.

Insert Table 2 about here

For both types of facts, there were significant three-way interactions on both tests of recognition [smaller immediate $\chi^2(2,116) = 8.74, p<.001$; smaller 14-day $\chi^2(2,116) = 8.05, p<.001$]. For facts addressing misconceptions, elaborative-interrogation subjects recognized more study statements with 100% certainty than did reading-control subjects (smaller $q = 8.05, p<.01$). Reading-control subjects selected more misconceptions than did their elaborative-interrogation counterparts. Specifically, reading-controls endorsed more misconceptions with 50% certainty on the immediate test of recognition than did elaborative-interrogation subjects ($q = 3.63, p<.05$), and more misconceptions with 100% certainty on the 14-day delayed test ($q = 3.58, p<.01$). No other differences were significant.

For novel facts, elaborative-interrogation subjects correctly identified more study information with 100% certainty than did reading-controls (smaller $q = 9.03, p<.01$). Elaborative-interrogation subjects also recognized more study facts with 50% certainty on the 14-
Table 2

Certainty Ratings for Immediate and 14-Day Delayed Questionnaires as a Function of Experimental Condition and Fact Type: Experiment 1

<table>
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<th></th>
<th>Correct Selections</th>
<th>Incorrect Selections</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100% SURE</td>
<td>50% SURE</td>
</tr>
<tr>
<td><strong>Immediate Sentence Selection Questionnaire</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facts Addressing Misconceptions</td>
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<td></td>
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<tr>
<td>Elaborative Interrogation</td>
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<td></td>
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<tr>
<td>X</td>
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<td>1.90</td>
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<tr>
<td>SD</td>
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<tr>
<td>%</td>
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<tr>
<td>SD</td>
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<td>%</td>
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<tr>
<td>Novel Facts</td>
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<td>Elaborative Interrogation</td>
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<td>%</td>
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<td>%</td>
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<td>Correct Selections</td>
<td>Incorrect Selections</td>
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</tr>
<tr>
<td>-------------------</td>
<td>----------------------</td>
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</tr>
<tr>
<td>100% SURE</td>
<td>50% SURE</td>
<td>100% SURE</td>
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14-Day Delayed Sentence Selection Questionnaire Facts Addressing Misconceptions

Elaborative Interrogation

<table>
<thead>
<tr>
<th>X</th>
<th>10.67</th>
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<th>1.27</th>
<th>1.03</th>
<th>.10</th>
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</thead>
<tbody>
<tr>
<td>SD</td>
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<td>2.89</td>
<td>.10</td>
<td>1.31</td>
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<td>.40</td>
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<td>%</td>
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<td>.21</td>
<td>7.92</td>
<td>6.46</td>
<td>.63</td>
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Reading Control

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<th>X</th>
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</thead>
<tbody>
<tr>
<td>SD</td>
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<td>1.50</td>
<td>1.95</td>
<td>2.16</td>
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<td>%</td>
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<td>12.50</td>
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14-Day Delayed Sentence Selection Questionnaire Novel Facts

Elaborative-Interrogation

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<tr>
<th>X</th>
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<th>2.40</th>
<th>.10</th>
<th>1.07</th>
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<tr>
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<td>2.45</td>
<td>.40</td>
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<tr>
<td>%</td>
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<td>15.00</td>
<td>.63</td>
<td>6.67</td>
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<td>.00</td>
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Reading Control

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<td>%</td>
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<td>8.41</td>
<td>12.07</td>
<td>1.51</td>
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Note. n = 30 for each condition.
day delayed test ($q = 3.58, p < .05$), although reading-controls recognized more facts with 50% certainty on the immediate test ($q = 4.40, p < .01$). There were no other significant differences between the two conditions for either correct selections ($q < 1.01, p > .05$) or incorrect selections ($q < 2.98, p > .05$) of novel facts.

**Free and Cued Recall Errors**

In order to determine whether learning gains due to elaborative interrogation were merely artifacts of more attempts at recall, errors produced during free and cued recall were analyzed. The subjects' responses were monitored for two types of errors: incorrect statements and misconceptions. Incorrect statements were facts generated during testing that did not correspond to information presented at study. The number of misconceptions expressed during recall was also analyzed. In general, both the numbers of incorrect statements and misconceptions were low (overall incorrect statement free recall mean = 1.40 per student; overall incorrect statement cued recall mean = 2.32 per student; overall misconception free recall mean = .22 per student; overall misconception cued recall mean = 1.00 per student). Incorrect statement and misconception means and standard deviations are listed for each passage in Table 3.

__________________________________________

**Insert Table 3 about here**
Table 3

Error Data: Incorrect Statements and Misconceptions for Free and Cued Recall as a Function of Experimental Condition and Passage: Experiment 1

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<th>Animals</th>
<th>Plants</th>
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<td>.00</td>
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<th>Animals</th>
<th>Plants</th>
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<tr>
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<tr>
<td>Incorrect Statements</td>
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<td>SD</td>
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For both free and cued recall tasks, a 2 (strategy) by 4 (passage) Anova, with repeated measures on the last variable, was carried out to analyze the number of incorrect statements. Because misconception errors could be traced to text type at study, a 2 (strategy) by 3 (text) by 4 (passage) mixed-model Anova was carried out for these data.

Most important, there were no significant differences in the number of incorrect statements or misconceptions generated by elaborative-interrogation and reading-control subjects on either the free or cued recall tasks, [larger incorrect statement $F(1,58) = 1.67, p > .05$; larger misconception $F(1,58) = .59, p > .05$]. Analysis of incorrect statements produced during free recall revealed no main effect for passage, $F(3,174) = 1.02, p > .05$, although there was a strategy by passage interaction, $F(3,174) = 3.25, p < .02$. For the solar system passage, elaborative-interrogation subjects generated more incorrect statements than did reading-control subjects ($g = 3.70, p < .05$).

For incorrect statements generated during cued recall, there was a main effect for passage ($F(3,174) = 7.07, p < .001$) and a significant strategy by passage interaction ($F(3,174) = 3.30, p < .02$). Students generated more inaccurate statements about plants than any other topic (smallest $g = 3.89, p < .05$), with reading-control
subjects producing significantly more incorrect statements than elaborative-interrogation subjects, $q = 3.70$, $p < .05$. There were no other significant differences of interest.

Analysis of the number of misconceptions generated during free and cued recall revealed a main effect for passage (free recall $F(3,174) = 3.63$, $p < .01$; cued recall $F(3,174) = 23.59$, $p < .001$). For free recall, students generated more misconceptions about plants than about the solar system ($q = 4.21$, $p < .01$), with students generating more misconceptions about plants than any other topic on the cued recall task (smallest $q = 8.61$, $p < .01$). There were no other significant differences between passages on either test, $q < 2.13$, $p > .05$.

The main effect for text was significant on the cued recall task ($F(2,116) = 14.90$, $p < .001$) but not for free recall ($F(2,116) = 2.50$, $p > .05$). For cued recall, students generated more misconceptions after reading inverted refutation text than either traditional text or refutation text (smaller $q = 5.48$, $p < .01$, with more misconceptions produced following the reading of traditional text than refutation text ($q = 10.02$, $p < .01$). There were no other significant differences of interest.

Relationship Between Study Responses and Subsequent Learning

The elaborative-interrogation study responses were scored for adequacy by two independent raters. Scoring
criteria similar to those used by Pressley et al. (1988) and Woloshyn et al. (1990) were used to score responses as either "adequate", "inadequate", or "no response". Adequate responses were those that used relevant background knowledge in a manner that made clearer why the given fact was true. All other responses were classified as inadequate. Failures to respond were classified as no response. Raters agreed on 89% of the response classifications, with discrepancies resolved by discussion.

Students provided adequate responses 34.70% of the time; inadequate responses 55.70% of the time; and no responses 9.60% of the time. For each of the four memory tests, the Spjotvoll and Stoline's modified HSD procedure was used to analyze differences between the categories, with conditional probability means and standard deviations listed in Table 4. There was only

Insert Table 4 about here

one significant difference: For the immediate sentence selection questionnaire, items answered with adequate responses were retained significantly more often than were items answered with no responses, $q = 3.87$, $p < .05$. No other comparisons were significant (largest $q = 2.35$).

Response adequacy was also analyzed separately for items underlying common misconceptions and novel science
Table 4

Answers Provided to Why Questions and Conditional Probabilities for Free Recall, Cued Recall, Immediate, and 14-Day Delayed Sentence Selection Questionnaires as a Function of Answer Type: Experiment 1

<table>
<thead>
<tr>
<th></th>
<th>Conditional Adequate Probability</th>
<th>Conditional Inadequate Probability</th>
<th>Conditional No Response Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Test</strong></td>
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<tr>
<td>Free Recall</td>
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<tr>
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<td>.304</td>
<td>.268</td>
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<td>.161</td>
<td>.136</td>
<td>.317</td>
</tr>
<tr>
<td>N</td>
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<td>.660</td>
<td>.661</td>
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<td>SD</td>
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<td>.308</td>
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<tr>
<td>N</td>
<td>30</td>
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<td>SD</td>
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<td>.072</td>
<td>.315</td>
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<tr>
<td>14-Day Delayed Sentence Selection Questionnaire</td>
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<td>X</td>
<td>.905</td>
<td>.842</td>
<td>.858</td>
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<tr>
<td>SD</td>
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<td>20</td>
</tr>
</tbody>
</table>
facts. Adequate answers accounted for 31.5% of the responses for science facts underlying misconceptions and 37.9% of the responses for novel science facts. Inadequate answers accounted for 59.2% and 52.3% of the two categories of responses; failures to respond accounted for 9.2% and 9.8% of the answers. For statements addressing common misconceptions, there was one significant difference on the immediate sentence selection questionnaire: Items with adequate answers were retained better than items that were associated with a response failure ($g = 3.43$, $p < .05$). No other categorical differences were significant for facts addressing misconceptions ($g \leq 2.17$, $p > .05$), nor were there any significant differences between the three response categories for novel facts ($g \leq 2.40$, $p > .05$).

**Posttest Interview**

Because self-report data can substantiate some processing differences between conditions (Pressley et al., 1987), they are reported here. Students were asked to share their thought processes (i.e., what exactly they were thinking about; what was going through their minds) for three probe items (one written in each of the three text types). Subjects in both the elaborative-interrogation and reading-control conditions reported adhering to their assigned study instructions more than to any other method of study (57.74% of the probes for
elaborative-interrogation students; 35.71% of the probes for reading-control students). Use of alternative processing strategies was infrequent for both groups (i.e., reading-for-understanding, and other elaboration strategies accounted for 12.73% of the elaborative-interrogation probes; elaboration strategies, for 9.52% of the reading-control probes). There were relatively no differences in the reported rate of already knowing the probe items between the two groups (i.e., 5.75% and 5.95%). Reading-control subjects, however, reported surprise and/or disbelief about the study information almost twice as often than did elaborative-interrogation students (35.71% versus 19.54% of the probes, respectively).

Subjects were also asked to rate the ease of their study task for each of the four topics, and the comprehensibility of the three types of text. The mean ratings of task and text difficulty/comprehensibility are summarized in Table 5. A 2 (strategy) by 4 (passage) Anova was carried out with repeated measures on passage. The main effect for strategy was not significant (critical $F = 4.00$, obtained $F(1,58) = 3.15, p > .05$), although elaborative-interrogation subjects rated their task as more difficult for all four passages than did reading-
Table 5

Task and Text Difficulty Ratings as a Function of Experimental Condition, Passage, and Text Type:

Experiment 1

<table>
<thead>
<tr>
<th>Task Difficulty</th>
<th></th>
<th>Text Difficulty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar System</td>
<td>Circulatory System</td>
<td>Animals Plants</td>
</tr>
</tbody>
</table>

Condition

Elaborative Interrogation

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<th>X</th>
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<th>5.63</th>
<th>4.37</th>
<th>4.80</th>
<th>4.10</th>
<th>5.03</th>
<th>5.13</th>
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</thead>
<tbody>
<tr>
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<td>2.25</td>
<td>2.42</td>
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Reading Control

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<th>4.07</th>
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<th>4.17</th>
<th>4.73</th>
<th>4.37</th>
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</thead>
<tbody>
<tr>
<td>SD</td>
<td>2.37</td>
<td>2.45</td>
<td>2.89</td>
<td>2.30</td>
<td>2.56</td>
<td>2.45</td>
<td>2.39</td>
</tr>
</tbody>
</table>

Note. Maximum rating = 10.

Note. 1 = Very Easy, 10 = Very Hard.

Note. n = 30 in each condition.
control subjects. There was a significant main effect for passage \((F(3,174) = 5.19, p < .002)\). The students rated both the circulatory system and the solar system passages more difficult to study than the animal passage (smallest \(q = 3.35, p < .05\). There was no significant interaction between strategy and passage \((F(3,174) = .60, p > .619)\).

The main effect for text was significant \((F(2,116) = 3.87, p < .02)\). Students rated traditional easier to comprehend than either refutation or inverted refutation text (smaller \(q = 3.04, p < .05\). There was no significant difference between students' comprehension ratings of refutation text and inverted refutation text (\(q = .65, p > .05\)). Descriptively, students perceived traditional text as the easiest to comprehend followed by inverted refutation text, with refutation text perceived as the most difficult to understand.

In summary, the results of this study provided four major findings. (1) Elaborative interrogation was an effective learning adjunct that helped students acquire both novel information and information that addressed their misconceptions. (2) The type of elaborative-interrogation study response had little impact on retention. Even when students failed to generate an answer to the why question, or generated an answer that contained irrelevant information, learning was facilitated relative to reading-for-understanding. (3) Students have
difficulty abandoning their inaccurate beliefs in favor of scientifically accepted facts on tests of recognition. This is true regardless of processing strategy, although the elaborative-interrogation strategy promoted better recognition for science facts than did reading for understanding. (4) Reading either refutation text or traditional text provided better retention than did reading inverted refutation text.

Discussion

The most striking finding of this study was that instructing students to answer "why" questions enhanced learning on both recall (free and cued recall) and recognition tasks (immediate and 14-day sentence selection questionnaires) relative to instructing students to read for understanding. That elaborative interrogation facilitated acquisition across all four memory tasks, even after a 14-day delay interval, both replicates and extends the findings of previous studies that have shown elaborative interrogation to be a very effective strategy (e.g., Pressley et al., 1989; Woloshyn et al., 1990; Wood et al., 1990). The elaborative-interrogation strategy is presumed to prompt learners to make inferences about incoming information based on their prior knowledge. This inferencing is believed to create or strengthen associations between incoming information and existing knowledge. Given that elementary-school children are
likely to have less relevant prior knowledge than adults (students were only able to provide adequate responses for approximately one-third of the why questions), it is especially encouraging that they could use the elaborative-interrogation strategy successfully.

The elaborative-interrogation strategy also enhanced students' confidence in their recognition decisions. Specifically, for both novel facts and facts about common misconceptions, elaborative-interrogation subjects made more correct selections with 100% certainty than did reading-controls. Perhaps even more important, when elaborative-interrogation subjects did make recognition errors about facts addressing misconceptions, they did so with significantly less certainty than did their reading-control peers. In other words, use of the elaborative-interrogation strategy promoted maximum confidence about correct selections and decreased confidence about incorrect selections, especially those concerning misconceptions.

Because elaborative-interrogation requires students to search for and generate answers to why questions, the strategy focuses their attention on information not explicitly stated in the study materials. Therefore, another possibility why elaborative interrogation facilitates learning is that the strategy prompts more attempts at recall. If this were true, error rates would
have been higher in the elaborative-interrogation condition than in the reading-control condition. In general, subjects generated few errors during recall. Except for two instances (one where elaborative-interrogation subjects produced more incorrect statements about the solar system during free recall; the other where reading-control subjects produced more incorrect statements about plants during cued recall), there were no significant differences in the number of incorrect statements or misconceptions expressed by subjects in the two learning conditions.

Conditional probabilities for type of answer generated to the elaborative-interrogation why question provided additional confirmation that the strategy is truly an effective learning adjunct. One might speculate that failures to generate adequate answers to study items would impede learning, perhaps because the students may have directed most of their study efforts to the unsuccessful search for a learning mediator rather than to the acquisition of the presented information, or they may even have focused their attention on irrelevant prior knowledge (Woloshyn, et al., 1990).

As in previous research with adults and, in some cases, children (e.g., Wood et al., 1990: Experiment 1), the quality of study response had little impact on retention (descriptively, there was a slight though
consistent advantage for items associated with adequate responses). Presumably, even when subjects are unable to provide an adequate response, their active attempts to do so enhance learning relative to reading-for-understanding. Attempting to generate an adequate response may activate a network of information that is related to the critical fact (e.g., Slamecka & Fevrieski, 1983). Alternatively, trying to answer the why question may promote more general mechanisms including increased task attention, arousal, effort, and deeper/more meaningful processing of facts (e.g., Jacoby, 1978; Hasher & Zacks, 1979; Slamecka & Graf, 1978; Tyler, Hertel, McCallum, & Ellis, 1979). Finally, retention gains may be an artifact of encoding similarity between study and test (i.e., both elaborative-interrogation encoding and retrieval tasks involved question answering; McDaniel, Friedman, & Bourne, 1978; Morris, Bransford, & Franks, 1977; Tulving & Thomson, 1973).

One possibility why elaborative interrogation aids learning is that it focuses students' attention on the facts as they are presented (e.g., Pressley et al., 1988). Consistent with this interpretation is the finding that students assigned to the elaborative-interrogation condition rarely expressed surprise or disbelief about the science statements. In fact, posttest interviews revealed that reading-control subjects were almost twice as likely
as elaborative-interrogation subjects to challenge the authenticity of the presented information, doing so for over one-third of the probe items. Furthermore, reading-control subjects made fewer attempts to reconcile discrepancies between their prior knowledge and the science information, allowing their inaccurate beliefs to override information presented in text.

For the free and cued recall memory tests, there appeared to be no differences between the acquisition of novel facts and facts addressing misconceptions. Conversely, on the immediate and 14-day sentence selection questionnaires, subjects recognized more novel facts than facts about which they had inaccurate beliefs, suggesting that they often allowed their misconceptions to override study information when making decisions about statement accuracy. This finding is similar to Lipson's (1983) work where grade 3 students favored their inaccurate beliefs over scientifically accepted facts after they were given intentional learning instructions to read science passages for understanding.

The differing demands of the recall and recognition tasks may be responsible, in part, for the differences in acquisition patterns associated with fact type. In order to be successful on either the free or cued recall tests, subjects had to both access (or retrieve) potential response information from memory and make a recognition
decision as to whether that information was presented at study (e.g., Wessells, 1982). Presumably, students tried equally hard to encode both types of science facts, inasmuch as they were given intentional learning instructions that emphasized acquisition of the scientifically accepted facts. Therefore, the probability of recalling the study statements should be about the same for the two types of facts. If students retrieved inaccurate information (i.e., misconceptions) in addition to the scientifically correct facts, the immediacy of the recall test might make the science facts seem more familiar, and thus, more likely to be selected. Finally, the recall tasks provided subjects with a no response option. Therefore, if conflicting information was retrieved at test and the subject could not make a recognition decision, he or she could skip the test item.

Recognition, on the other hand, differs from recall in that subjects do not need to retrieve critical information stored in memory -- the target information is presented at test (Wessells, 1982). However, subjects still need to decide whether the presented information corresponds to study information. Both true and false statements were presented in the sentence selection questionnaires, thus increasing the likelihood that both scientifically correct and incorrect associations were activated. Because the students would have to select from
competing associations, they would be more likely to make an incorrect sentence selection decision about science facts that addressed their inaccurate beliefs (presumably, they would have more inaccurate prior associations for this information than novel information). Moreover, the forced choice recognition format did not provide students the option of skipping test items. Finally, the sentence selection instructions may have prompted students to make incorrect decisions -- they were instructed to select the one statement that they believed was correct. This may have been particularly important in the delayed test where subjects were not given explicit instructions to refer back to study information.

Analyses of the three types of text revealed that there was no memory advantage associated with reading inverted refutation text relative to reading either traditional text or, for the most part, refutation text. There are two possible reasons why inverted refutation text failed to enhance retention relative to the other types of text. First, students may not have profited from reading this form of text (i.e., support for the science fact and refutation of a common misconception) if they stopped processing information after encountering the true fact, which was presented first. The study instructions may have promoted students to prematurely terminate their study inasmuch as students were instructed to pay special
attention to the science facts.

Another possibility is that students did process all the information presented in inverted refutation text but for some reason primarily attended to the last item presented, in this case the misconception. Analysis of cued recall responses revealed that students generated more misconceptions after reading inverted refutation text than after either of the other two texts. However, this finding needs to be interpreted cautiously given that the number of generated misconceptions was modest, with the majority of instances (45%) addressing the science statement, "Plants do not eat soil."

There appeared to be some advantage for reading refutation text relative to reading traditional text, although this advantage was not consistent across all the memory tests and conditions. Retention advantages for refutation text are likely due to the presentation of both a misconception and the scientifically accepted fact. Because misconceptions were refuted in an impersonal and nonthreatening manner (i.e., text was written so that attention was drawn to what some people wrongly believe and not to the students' incorrect beliefs), refutation text probably encouraged students to make comparisons between their existing beliefs and scientifically accepted thought. Posttest comments made by some students, especially reading-control subjects, confirmed that
refutation text did promote this type of reflection. Because text manipulation was a within-subjects variable, it is possible that there were carry-over effects to traditional text. Specifically, subjects may have continued to make comparisons between their existing knowledge and the presented science facts when reading traditional text. If so, retention differences as a function of text type would not be expected. Although, this generalization is unlikely given previous findings that learners do not readily transfer skills across tasks, even when task demands remain relatively constant (e.g., Pressley & Schneider, 1990), the possibility of carry-over effects could be controlled by investigating text as a between-subjects variable.
Experiment 2

Given that instructions to use elaborative interrogation enhanced learning for both information that was consistent and inconsistent with the learners' prior knowledge, a second study was carried out. The aims of Experiment 2 were first, to replicate the finding that instructions to use elaborative-interrogation facilitates acquisition of science facts relative to instructions to read for understanding and, second, to investigate the effects of instructions to activate prior knowledge before study.

Forty students in each of grades 6 and 7 were tested. All participants were instructed to learn individually presented science facts. Students were assigned to either elaborative-interrogation or reading-control study conditions. Half of the presented information was consistent with learners' prior knowledge, whereas the remaining facts were inconsistent with their prior knowledge. Because elaborative interrogation is believed to prompt students to use prior knowledge in a manner that supports facts as they are presented, students given elaborative-interrogation instructions were expected to remember more study facts than students given reading-control instructions.

In order to assess the role of activation and
strategy use, half the participants in each study condition were given instructions designed to activate prior knowledge about the to-be-learned topics before study. The remaining students were similarly prompted to activate prior knowledge about unrelated topics. Based on the findings of previous investigations, it was expected that reading-controls who activated prior knowledge that was inconsistent with text would allow their prior knowledge to override text information and perform more poorly on memory tests than reading-control subjects who activated prior knowledge about unrelated content (i.e., "nonactivators"). However, activators should have superior retention for to-be-learned items that are consistent with their prior knowledge relative to nonactivators.

It was unclear how activation instructions would affect elaborative-interrogation students' retention for study information. When learners activate knowledge that can be used as part of a supportive elaborative-interrogation response (i.e., information that is consistent with text), the time necessary to search memory for an answer to the why question may be reduced, allowing learners more time to establish a meaningful association. On the other hand, activation of information that cannot be used as part of a supportive elaborative-interrogation response (i.e., information that is inconsistent with
text) may either have no affect on long-term memory search
or jeopardize the adequacy of the why responses (i.e.,
subjects may use the activated, inaccurate information as
part of an elaborative-interrogation response rather than
search for more appropriate prior knowledge).

Because retention benefits associated with the use
of refutation text were not clear in Experiment 1, and
because students expressed difficulty comprehending
refutation text, traditional text was adopted for all
critical materials in Experiment 2. Investigation of text
type may have also confounded interpretation of learning
gains due to activation and strategy instructions,
especially interactive effects.

Retention of the presented facts was evaluated
using the same memory measures as in Experiment 1 (i.e.,
free recall, cued recall, immediate sentence selection
questionnaire, and 14-day sentence selection
questionnaire). In addition, students participated in 75-
day and 180-day sentence selection questionnaires.

Method

**Sentence Selection Pretest Questionnaire**

Prior to participating in the experimental session,
60 students in grade 6 (24 males, 36 females, \( X = 10.95 \)
years, \( SD = .58 \) years) and 72 students in grade 7 (29
males, 43 females, \( X = 11.97 \) years, \( SD = .47 \) years)
completed a sentence selection questionnaire similar in
format to the one used to select materials in Experiment 1, except that students did not have to indicate the source of their knowledge (e.g., school, texts, television). The questionnaire consisted of 90 items including the 18 critical statements about common misconceptions that were used in the first study. The questionnaire took no longer than 45 minutes to complete. Sentence selection pretest performance scores were used to (a) confirm the appropriateness of facts addressing common misconceptions and, (b) provide a comparison measure of learning for these facts following study. As in Experiment 1, items that addressed misconceptions were those for which at least 50% of the children in each grade selected the false statement as correct with at least 50% certainty (range = 50% to 88%, mean = 65%). Novel statements that were used in Experiment 1 were not included in the questionnaire so that these materials would be truly novel.

Subjects

The participants were 40 grade 6 students (14 males, 26 females, \( X = 11.0 \) years SD = .60 years) and 40 grade 7 students (17 males, 23 females, \( X = 12.0 \) years SD = .45 years) attending four Canadian public schools. Participation criteria were the same as in Experiment 1. All students completed the pre-test sentence selection questionnaire. Ten participants from each grade were
randomly assigned to one of the four experimental conditions: activated elaborative-interrogation, nonactivated elaborative-interrogation, activated reading-to-understand control, and nonactivated reading-to-understand control. The subjects were tested individually and in a quiet setting. The experimental session lasted approximately 45 minutes.

Materials

Two sets of 32 factual statements were used in this study (listed in Appendix F). Half of these statements were about novel facts that were consistent with the learners' prior knowledge, whereas the remaining statements were about facts that were inconsistent with their existing beliefs (i.e., common misconceptions. All statements were written in traditional text (i.e., science fact only). Statements were typed in upper case on 12.5 cm by 19.5 cm blank cards. An audio recording was made for each set of experimental materials to help ensure that all subjects processed the factual statements at least once. As in Experiment 1, subjects were provided with four practice sentences, two of which were consistent with their prior knowledge and two of which were inconsistent with their existing knowledge.

An orienting instruction was typed in upper case on a stand-up cue card that was placed in front of each subject. The prompts were, "Read the sentence out loud at
a rate that allows you to understand that this fact is true," and, "Why is that fact true?" for the reading-control and elaborative-interrogation conditions respectively. The subjects' responses were tape recorded using a Sony portable recorder and clip microphone. The tape machine was placed in full view of each child.

**Procedure**

The experimental session consisted of eight phases: activation, instruction, study, free recall, cued recall, posttest interview, immediate sentence selection questionnaire, and delayed sentence selection questionnaire. There were three tests of delayed recognition: 14-day, 75-day, and 180-day.

**Activation**

To start the experimental session, students were asked to participate in a "warm up" activity. Specifically, students were told that this activity was intended to help them feel more at ease with the experimental procedure (i.e., talking into a tape recorder), and the presence of the investigator. The experimenter presented each student with the four topic titles. For subjects assigned to the activation conditions, the topic headings corresponded with the four to-be-learned content areas (i.e., solar system, circulatory system, plants, and animals). For the remaining subjects, the topic headings were about four
unrelated topics (i.e., natural disasters, pollution, water, and Canada).

Students were given 1.5 minutes to respond to each topic (pilot subjects confirmed that this was an adequate interval in which to generate conversation yet avoid boredom and/or frustration). Specifically, they were instructed to generate a conversation about the title by telling the experimenter everything that they knew about the topic. In order to help them generate conversation, the subjects were instructed to talk about the first things that came to mind. They were told that they could reflect on information that they had acquired in their classes, readings, or daily experiences. They were also told that presenting their ideas in point form was sufficient. The students were instructed to wait for the experimenter's signal to begin and stop responding. This procedure was repeated for each of the four topic cards.

Two factors influenced the decision to have subjects respond aloud to the activation prompts rather than in writing as previous researchers have done (e.g., Alvermann, et al., 1985; Smith, et al., 1984). First, it was believed that responding aloud would help subjects become more at ease with having their responses tape recorded. Second, it was believed that quantitatively more information would be obtained from students using a talk aloud procedure than a written procedure. The
activation responses were transcribed and analyzed for additional confirmation that the study information contained facts that were consistent, and facts that were inconsistent, with students' existing beliefs.

**Instructions**

Participants were given study instructions identical to those used in Experiment 1. Specifically, all students were told that they would see individual sentences stating true facts about four different topics and that several statements about the same topic would be presented sequentially. The subjects were told that they would be asked about the presented information at a later time.

Subjects assigned to the reading-control conditions were asked to read each statement out loud and in a continuous manner for the entire time that the statement was presented. It was stressed that they should read the statements at a rate that allowed them to understand the presented information. Subjects assigned to the elaborative-interrogation conditions were instructed to read each statement silently and to answer why each fact is true. These students were instructed to reflect upon information that they had acquired in their classes, readings, and everyday experiences to help them answer the "why" questions.

Subjects were required to demonstrate how they would carry out their required processing task with the four
practice sentences. Subjects were given feedback about each of their practice responses and an example of an appropriate response. The 32 to-be-learned statements were then presented individually for 15 seconds. Instructions for each condition were reiterated when appropriate. In order to control for ordering effects, two different presentation formats were constructed for each set of materials, with half the students in each condition and grade randomly assigned to each order.

Retention Tests and Posttest Interview

The same retention measures that were used to assess learning in Experiment 1 were also used in this experiment. That is, subjects were asked to complete two tests of recall (free and cued recall) and two tests of recognition (immediate and 14-day sentence selection questionnaires). In addition, the students completed the sentence selection questionnaires at 75-day and 180-day intervals following the experimental session. For the tests of recall, subjects were instructed to try to remember as many of the presented facts as possible, given only the titles of the content areas (i.e., free recall). The experimenter then provided the subjects with prompts (i.e., cued recall) for information that was not recalled spontaneously during free recall. All subjects were told that they would probably remember more target items if they reflected on how they processed information during
study. For the sentence selection questionnaires, they were instructed to select from pairs of sentences the statement that they believed to be true. Students completed the delayed questionnaires with their homeroom instructors, and were not explicitly instructed to refer to information presented at study.

Students were also asked to complete a posttest interview similar to the one used in Experiment 1. Subjects were asked to rate how difficult they found their assigned study task for each of the topics, and to indicate whether they enjoyed engaging in their assigned strategy. Eight subjects from each grade and condition (i.e., 30% of the participating subjects) were also asked to elaborate on their thought processes for four of the study statements.

Results

Format

Statistical procedures similar to those in Experiment 1 were used to analyze recall (i.e., free and cued) and recognition responses (i.e., immediate, 14-day, 75-day, and 180-day delayed sentence selection questionnaires). The maximum score for each dependent measure was 32 (i.e., 16 points for facts addressing common misconceptions; 16 points for novel facts). Two independent raters scored 50% of subjects' free and cued recall responses for consistency with study information. Interrater agreement
was 98% for both free recall and cued recall responses. All disagreements were resolved by discussion. Given the high interrater reliability, the remaining data were scored by only one of the raters.

Again, the learning gains due to strategy were reported separately from those due to type of fact and activation instructions (i.e., the primary objective of this experiment was to replicate the positive finding that elaborative interrogation enhances learning of science facts that are consistent, and science facts that are inconsistent, with students' prior knowledge). In order to ensure that cued recall scores were not contaminated by free recall, the subjects' cued recall responses were analyzed both with and without free recall scores.

The students' certainty ratings (i.e., 100% Sure, 50% Sure, and 100% Unsure) were analyzed for both correct and incorrect decisions across all four tests of recognition. As a further measure of learning gain, a pretest versus posttest comparison of subjects' certainty ratings was carried out for items that addressed common misconceptions. In order to ensure that learning gains associated with the use of the elaborative learning strategy were not artifacts of more retrieval attempts, errors generated during free and cued recall were analyzed.

As in Experiment 1, secondary analyses included
monitoring the relationship between subjects' study responses and subsequent memory performances across all the dependent measures. All students' posttest interview responses were analyzed to obtain information regarding task difficulty and study enjoyment.

Learning Gains Due to Strategy

Subjects' raw scores were converted into probabilities (to facilitate comparison with students' performances in Experiment 1), with means and standard deviations for each condition and dependent measure listed in Table 6. For each of the six dependent measures, a 2 (strategy) by 2 (activation) by 2 (fact) ANOVA was carried out, with repeated measures on the last variable. Tukey's HSD test was used to determine specific group differences.

For both free and cued recall tasks, there were significant main effects for strategy (free recall $F(1,76) = 50.31, p<.001$; cued recall $F(1,76) = 76.13, p<.001$), such that elaborative-interrogation subjects recalled more study information than did reading-control subjects (smaller $g = 7.82, p<.05$). The cued recall scores were also analyzed independent of students' free recall responses (i.e., students' free recall scores were subtracted from cued recall responses). The main effect for strategy remained significant, $F(1,76) = 22.27, p<.03$. 

Insert Table 6 about here
Table 6

**Means and Standard Deviations for Free Recall, Cued Recall, Immediate, 14-Day, 75-Day, and 180-Day Delayed Sentence Selection Questionnaires as a Function of Experimental Condition, Activation, and Fact Type:**

**Experiment 2**

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<th>Facts About Science Misconceptions</th>
<th>Novel Facts</th>
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<td>Activation</td>
<td>Nonactivation</td>
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<td>Condition</td>
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<td>Free Recall</td>
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<td>.284</td>
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<td>X</td>
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<tr>
<td>SD</td>
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<td>.090</td>
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<td>Cued Recall With Free Recall</td>
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**Condition**

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<tr>
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<td>.150</td>
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<td>Reading Control</td>
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<td>X</td>
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<td>.397</td>
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<tr>
<td>SD</td>
<td>.111</td>
<td>.181</td>
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</table>

<p>| Immediate Sentence Selection Questionnaire |
| Elaborative-Interrogation |
| X                    | .913        | .878                | .984       | .959          |
| SD                   | .082        | .094                | .028       | .058          |
| Reading Control      |
| X                    | .722        | .753                | .844       | .916          |
| SD                   | .174        | .181                | .174       | .110          |</p>
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<th></th>
<th>Facts About Science Misconceptions</th>
<th>Novel Facts</th>
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<td>Nonactivation</td>
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<td><strong>Condition</strong></td>
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<td><strong>14-Day Delayed</strong></td>
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<td>Sentence Selection Questionnaire</td>
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<td>Elaborative-Interrogation</td>
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<td><strong>75-Day Delayed</strong></td>
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<tr>
<td>Elaborative-Interrogation</td>
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<tr>
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<td>.747</td>
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<td>.114</td>
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<td>Reading Control</td>
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<tr>
<td>SD</td>
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<td>.160</td>
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<th>Novel Facts</th>
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<td>Nonactivation</td>
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<td>180-Day Delayed</td>
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<td>Sentence Selection Questionnaire</td>
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<tr>
<td>Elaborative-Interrogation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>0.723</td>
<td>0.750</td>
</tr>
<tr>
<td>SD</td>
<td>0.098</td>
<td>0.138</td>
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<tr>
<td>Reading Control</td>
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<tr>
<td>X</td>
<td>0.507</td>
<td>0.516</td>
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<tr>
<td>SD</td>
<td>0.174</td>
<td>0.234</td>
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</table>

Note. n = 40 for each condition (free recall to 75-delayed sentence selection questionnaire).

Note. For 180-day delayed sentence selection questionnaire: elaborative-interrogation n = 39, reading-control n = 38.

a Facts addressing common misconceptions.
b Novel facts.
Instructions to use elaborative interrogation produced superior performance scores relative to reading-control instructions ($q = 5.16$, $p<.01$).

For all measures of recognition (i.e., immediate, 14-day, 75-day and 180-day delayed sentence selection questionnaires), the main effect for strategy was significant at all retention intervals ($F(1,73-76) \geq 20.40$, $p<.001$). Elaborative interrogation subjects recognized more study information than did reading-control subjects ($q \geq 5.58$, $p<.01$).

As an additional measure that elaborative interrogation was an effective learning strategy, subjects' pretest and posttest performances were analyzed for facts addressing common misconceptions (i.e., elaborative-interrogation learning gains may be confounded, inasmuch as not all students possessed inaccurate beliefs about facts addressing common misconceptions -- that is, these items were selected on the basis that 50% or more of the students in each grade held inaccurate beliefs about the statements). Specifically, the number of instances where subjects answered test items incorrectly at pretest, but correctly at posttest, were monitored across the two study conditions. Four, one-way Anovas were carried out. For each recognition measure, elaborative-interrogation subjects demonstrated greater learning gains than did
reading-controls \( \text{smallest } F(1,70) \geq 8.16, p<.001; \ g \geq 4.04, p<.01 \).

**Learning Gains Due to Activation and Fact Type**

For the free recall task, there was a significant main effect for activation \( F(1,76) = 4.55, p<.036 \), but not for fact \( F(1,76) = 1.30, p>.05 \). The activation by fact interaction was significant \( F(1,76) = 5.43, p<.02 \). Instructions to activate prior knowledge about unrelated information (i.e., nonactivation) enhanced recall relative to instructions to activate relevant prior knowledge (i.e., activation), \( g = 2.35, p<.05 \). The nonactivation advantage was limited to novel facts, \( g = 4.41, p<.01 \).

For cued recall, both with and without free recall scores, the main effect for fact was significant \( \text{smaller } F(1,76) = 5.92, p<.02 \). When subjects' cued recall scores were analyzed independent of free recall, there was also a main effect for activation, \( F(1,76) = 5.07, p<.03 \). There were no significant interactions.

Subjects recalled more information addressing science misconceptions than novel facts (cued plus free recall \( g = 4.67, p<.01 \); cued without free recall \( g = 3.45, p<.05 \)). When free recall responses were subtracted from cued recall scores, activators recalled more study information than did nonactivators, \( g = 2.45, p<.05 \).

For all measures of recognition, there was a significant main effect for fact at every retention
interval \( (F(1,73-75) \geq 60.36, p<.001) \). For the immediate, 75-day, and 180-day delayed questionnaires, there were significant interactions between fact and strategy \( (F(1,73-76) \geq 5.43, p<.02) \). There were no main effects for activation (largest \( F(1,73-76) = .47, p>.05) \).

Students were better able to correctly recognize novel study facts than facts contradicting common misconceptions (smallest \( \eta = 10.99, p<.01) \). Analysis of the strategy by fact interaction confirmed that students in both the elaborative-interrogation and reading-control conditions had more difficulties correctly recognizing facts addressing common misconceptions than novel facts (smallest \( \eta = 3.88, p<.01) \). Regardless of the type of fact, elaborative-interrogation subjects recognized more facts than did reading-control subjects on the immediate sentence selection questionnaire (smaller \( \eta = 4.65, p<.01) \), with elaborative-interrogation subjects recognizing as many study facts that addressed misconceptions as reading-control subjects recognized novel facts (\( \tau = .78, p>.05) \). This interaction was repeated for both 75-day and 180-day sentence selection questionnaires (larger \( \eta = 1.86, p>.05) \).

**Certainty Responses for Sentence Selection Questionnaires**

The subjects' certainty responses (i.e., 100% Sure, 50% Sure, 100% Unsure) were analyzed for each of the
delayed sentence selection questionnaires. Facts that addressed misconceptions were analyzed separately from novel facts. Of primary interest were the interactions involving strategy, accuracy, and certainty (there could be no main effect for strategy given that all students provided responses to the critical items). Because students' made recognition decisions about statements that underlie common misconceptions both before and after study, pretest responses for these items were also analyzed. Presumably, response patterns would not differ between the experimental conditions on the pretest measure, but would differ on the posttest measures. A 2 (strategy) by 2 (accuracy) by 3 (certainty) Anova with repeated measures on the last two variables, was carried out for each of the five sentence selection questionnaires. Table 7 lists the certainty responses

Insert Table 7 about here

for each questionnaire as a function of accuracy, fact type, and experimental condition.

For the pretest questionnaire, the strategy by accuracy and strategy by certainty interactions were not significant (F(1,78) = .45, p>.05; F(2,156) = 1.03, p>.05 respectively). The accuracy by certainty interaction was significant (F(2,156) = 46.19, p<.001), with students providing incorrect responses with 100% and 50% certainty
Table 7

**Certainty Ratings for Immediate, and 14-Day Delayed Questionnaires as a Function of Experimental Condition and Fact Type: Experiment 2**

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<th>Correct Selections</th>
<th>Incorrect Selections</th>
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</thead>
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<td></td>
<td>100%</td>
<td>50%</td>
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<tr>
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<td>SURE</td>
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<td>1.70</td>
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<td>%</td>
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<td><strong>Immediate Sentence Selection Questionnaire Facts Addressing Misconceptions</strong></td>
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<td>%</td>
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<tr>
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### 14-Day Delayed Sentence Selection Questionnaire

#### Novel Facts

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<td>50% SURE</td>
</tr>
<tr>
<td></td>
<td>100% SURE</td>
<td></td>
</tr>
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<tr>
<td>SD</td>
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<td>.61 .87 .11</td>
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<tr>
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<td>77.88 13.94 1.76</td>
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</table>

#### Reading Control

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</tr>
<tr>
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### 75-Day Delayed Sentence Selection Questionnaire

#### Facts About Misconceptions

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<td></td>
<td>100% SURE</td>
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<td>1.53 2.23 .38</td>
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<td>1.41 2.07 1.23</td>
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#### Reading Control

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<tr>
<td>%</td>
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<td>X</td>
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<td>50% SURE</td>
</tr>
<tr>
<td>100% SURE</td>
<td>100% SURE</td>
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180-Day Delayed Sentence Selection Questionnaire Novel Facts

Elaborative-Interrogation

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<th></th>
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<td></td>
</tr>
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<td></td>
</tr>
</tbody>
</table>

Reading Control

<p>| | | |</p>
<table>
<thead>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
more often than correct responses with the same certainty ratings (100% q = 19.52, p<.01; 50% q = 13.15, p<.01).

For both types of facts, there were three-way interactions of strategy, accuracy, and certainty at each retention interval [facts addressing misconceptions $F(2,156) \geq 9.35$, $p<.001$; novel facts $F(2,156) \geq 2.94$, $p<.05$]. For facts addressing common misconceptions, elaborative-interrogation students identified more study statements with 100% certainty than did reading-control students at every posttest measure (smallest $q = 8.35$, $p<.01$). Elaborative interrogation subjects also made more correct selections with 50% certainty on the 180-day delayed test ($q = 3.43$, $p<.05$). On every measure, reading-control subjects made more erroneous decisions with 100% certainty than did elaborative-interrogation subjects (smallest $q = 4.74$, $p<.01$). At 75-day and 180-day delay, reading-control students also made more errors with 50% certainty than did elaborative-interrogation students, smaller $q = 3.43$, $p<.05$.

For novel items, elaborative-interrogation subjects recognized significantly more study facts with 100% certainty than did their reading-control peers at each retention interval (smallest $q = 4.49$, $p<.01$). There were no other significant differences between the experimental conditions (largest $q = 2.98$, $p>.05$).
Free and Cued Recall Errors

As in Experiment 1, the subjects' free and cued recall responses were analyzed for errors to ensure that elaborative-interrogation learning gains were not artifacts of more recall attempts. The total number of errors included incorrect statements and misconceptions. Students generated relatively few errors during recall (overall incorrect statement free recall mean = 1.59 per student; overall incorrect statement cued recall mean = 2.81 per student; overall misconception free recall mean = .15 per student; overall misconception cued recall mean = .95 per student). Error means and standard deviations for each of the study conditions are listed in Table 8.

Insert Table 8 about here

For both free and cued recall, a 2 (strategy) by 2 (activation) by 4 (passage) Anova, with repeated measures on passage, was carried out. Most important, there were no significant differences in the number of incorrect statements or misconceptions generated by subjects in the two study conditions on either measure of recall (larger incorrect statement \( F(1, 76) = 1.53, p > .05 \); larger misconception \( F(1, 76) = 1.64, p > .05 \)).

Analysis of incorrect statements and misconceptions produced at free recall failed to reveal significant
Table 8

**Error Data: Incorrect Statements and Misconceptions for Free and Cued Recall as a Function of Experimental Condition, Activation Instructions, and Passage:**

**Experiment 2**

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<th>Nonactivators</th>
</tr>
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<tbody>
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<td>$s^a$ $c^b$ $p^c$ $A^d$</td>
</tr>
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<td>Condition</td>
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<td></td>
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<tr>
<td>----------------------</td>
<td>------------</td>
<td>---------------</td>
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<tr>
<td>Free Recall</td>
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<td></td>
</tr>
<tr>
<td>Incorrect Statements</td>
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<td></td>
</tr>
<tr>
<td>Elaborative Interrogation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>.55 .35 .25 .35</td>
<td>.30 .40 .10 .70</td>
</tr>
<tr>
<td>SD</td>
<td>.69 .59 .67 .44</td>
<td>.57 .60 .31 .87</td>
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<td>Reading Control</td>
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<tr>
<td>X</td>
<td>.35 .30 .30 .45</td>
<td>.40 .50 .55 .50</td>
</tr>
<tr>
<td>SD</td>
<td>.59 .57 .47 .69</td>
<td>.82 .69 .83 .83</td>
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**Free Recall**

**Misconceptions**

<table>
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<th>Nonactivators</th>
</tr>
</thead>
<tbody>
<tr>
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<td>$s^a$ $c^b$ $p^c$ $A^d$</td>
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<tr>
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<tr>
<td>X</td>
<td>.00 .10 .00 .25</td>
<td>.00 .00 .10 .00</td>
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<tr>
<td>SD</td>
<td>.00 .45 .00 .55</td>
<td>.00 .00 .31 .00</td>
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<tr>
<td>Reading Control</td>
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<td></td>
</tr>
<tr>
<td>X</td>
<td>.35 .30 .30 .45</td>
<td>.40 .50 .55 .50</td>
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<tr>
<td>SD</td>
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<td>.82 .69 .83 .83</td>
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<th>Condition</th>
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<th>Incorrect Statements</th>
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<td>X</td>
<td>.50</td>
<td>.25</td>
</tr>
<tr>
<td>SD</td>
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<td>.15</td>
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<td>SD</td>
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<td>.37</td>
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<td>.05</td>
</tr>
<tr>
<td>SD</td>
<td>.31</td>
<td>.22</td>
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</tbody>
</table>

**Note.**
- a = Solar System
- c = Circulatory System
- e = Animals
- d = Plants
effects for activation \( (\text{larger } F(1,76) = .61, p>.05) \), nor were there any significant interactions (largest \( F(3,228) = 2.91, p>.05 \)). When the number of misconceptions generated during free recall were analyzed, there was a main effect for passage \( (F(3,228) = 3.94, p>.05) \). Students generated more misconceptions about plants than about either the solar or the circulatory systems, smaller \( q = 3.35, p<.05 \). There was no main effect for passage when incorrect statements were analyzed, \( F(3,228) = 1.31, p>.05 \).

For cued recall, analysis of incorrect statements revealed significant main effects for activation \( (F(1,76) = 4.95, p<.03) \) and for passage \( (F(3,228) = 11.41, p<.001) \). Nonactivators produced more incorrect statements than did activators \( (q = 2.22, p<.05) \), with all subjects generating more inaccurate statements about the circulatory system than animals and about plants than any other topic (smallest \( q = 3.63, p<.05 \)). There were no other significant differences between topics (larger \( q = 2.42, p>.05 \)).

When the number of misconceptions generated during cued recall were analyzed, there was no significant effect for activation \( (F(1,760 = .87, p>.05) \). The main effect for passage was significant \( (F(3,228) = 34.86, p<.001) \), as was the activation by passage interaction \( (F(3,228) = 3.27, p<.02) \). Students produced more misconceptions about
plants than about any other topic (smallest $g = 11.24$, $p<.01$), with activators producing more plant misconceptions than nonactivators ($g = 4.17$, $p<.05$).

**Activation Responses**

In order to further ensure that there were no differences between subjects prior to study, the number of words and ideas produced during activation were analyzed. A 2 (strategy) by 2 (activation) by 4 (passage) ANOVA, with repeated measures on the last variable, was used. The word tally was comprised of the number of recognizable words students produced for each passage. For each complete thought, a word phrase was credited as an idea. No additional credit was given for paraphrased or repeated ideas. Table 9 lists the number of words and ideas generated for each topic.

There were no differences in either the number of words or the number of ideas produced by students assigned to either of the two study conditions [word $F(1,76) = 1.50, p>.05$; idea $F(1, 1,76) = 3.07, p>.05$] or activation modes [word $F(1,76) = .01, p>.01$; idea $F(1,76) = .10, p>.05$]. There were significant interactions of activation by word ($F(3,228) = 20.40, p<.001$), and activation by idea ($F(3,228) = 13.69, p<.001$). For both number of words and ideas, activators produced significantly more responses...
Table 9
Means and Standard Deviations of Words and Ideas Generated at Activation as a Function of Experimental Condition, Activation Instructions, and Passage: Experiment 2

<table>
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<tr>
<th>Condition</th>
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<th>Nonactivators</th>
</tr>
</thead>
<tbody>
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<td>c&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>SD</td>
<td>34.13</td>
<td>32.99</td>
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<td>X</td>
<td>96.55</td>
<td>109.15</td>
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<tr>
<td>SD</td>
<td>29.81</td>
<td>42.37</td>
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<table>
<thead>
<tr>
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<th>Nonactivators</th>
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<tbody>
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<tr>
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<td>20.50</td>
<td>15.25</td>
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<td>SD</td>
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<td>15.25</td>
</tr>
<tr>
<td>SD</td>
<td>4.16</td>
<td>3.24</td>
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</table>

than did nonactivators on the last passage about animals and Canada respectively (word \( q = 4.45, p < .05 \); idea \( q = 4.39, p < .01 \)). For number of ideas, nonactivators generated more responses than activators on the second passage about pollution and the circulatory system respectively, \( q = 4.21, p < .05 \).

There were significant passage effects for word (\( F(3,228) = 9.21, p < .001 \)) and idea (\( F(3,228) = 13.83, p < .001 \)). Because students assigned to different activation modes addressed different content areas, separate pairwise comparisons were carried out for activators and nonactivators to assess differences between the passages. Activation subjects generated more words and ideas about animals than they did about any other topic (smallest word \( q = 5.86, p < .01 \); smallest idea \( t = 5.25, p < .01 \)). More ideas were produced about the solar system and plants than about the circulatory system (smaller \( q = 6.34, p < .01 \)). No other differences were significant (largest \( q = 1.12, p > .05 \)).

Students assigned to the nonactivation conditions, generated more words about pollution than the other topics (smallest \( q = 5.35, p < .05 \)). More words were generated about water than about natural disasters and Canada (smaller \( q = 7.66, p < .01 \)). Students produced significantly fewer ideas about natural disasters than other topics (smallest \( q = 6.04, p < .01 \)). No other
differences were significant (largest \( g = 1.12, p > .05 \)).

Activation students' responses were also analyzed to confirm that the study facts tapped information about which students possessed misconceptions (i.e., activation responses were scrutinized for information that was inconsistent with the science information presented at study). Table 10 lists the number of misconceptions activated by students for each study passage. A response

\[ \text{Insert Table 10 about here} \]

was scored as a misconception if it was inconsistent with study information. No additional credit was given for paraphrased or repeated concepts. On average, the students activated 3.00 ideas that were inconsistent with the target information. Although this number represents only a small percentage of all the activated responses (i.e., 4.03%), it does represent approximately one-fifth of the target misconceptions (i.e., 18.75%).

There were no significant differences in the number of misconceptions expressed during activation by elaborative-interrogation and reading-control subjects \( [F(1,38) = 1.94, p > .05] \). There was a significant main effect for passage \( [F(3,114) = 24.50, p < .001] \). The subjects activated approximately the same number of inconsistent ideas about plants and the circulatory system \( (g = 2.11, p > .05) \), which, in turn, were greater than the
Table 10

**Means and Standard Deviations for Activated Misconceptions About Study Information as a Function of Experimental Condition and Passage: Experiment 2**

<table>
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<th>Activators</th>
<th>Solar System</th>
<th>Circulatory System</th>
<th>Animals</th>
<th>Plants</th>
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<tr>
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<td>1.13</td>
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<td>Reading Control</td>
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<td></td>
</tr>
<tr>
<td>(X)</td>
<td>.25</td>
<td>1.05</td>
<td>.00</td>
<td>1.40</td>
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<tr>
<td>(SD)</td>
<td>.44</td>
<td>.95</td>
<td>.00</td>
<td>.88</td>
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</table>
number of inconsistent ideas activated about the solar system and animals, with more misconceptions about the solar system than animals (smallest $\eta = 3.81$, $p < .01$).

**Study Responses**

The same raters that scored study responses for Experiment 1, scored the elaborative-interrogation study 2 responses in Experiment 2. Using the same scoring criteria, raters agreed on 89% of the response classifications. Discrepancies were resolved by discussion.

Students provided adequate responses 46.40% of the time, inadequate responses 43.60% of the time, and no responses 10.00% of the time. The mean conditional probabilities for adequate, inadequate, and no response items are listed in Table 11. The Spjotvoll and Stoline

---

Insert Table 11 about here

---

modified HSD procedure was used to analyze differences between the categories. For cued recall, items answered adequately were retained better than items that were not answered ($\eta = 3.51$, $p < .01$). There were no other significant differences between the response categories on either the recall or recognition tasks ($\eta \leq 1.50$, $p > .05$).

The effect of study response adequacy was analyzed separately for items addressing misconceptions and novel facts. Adequate answers accounted for 46% and 46.9% of
Table 11

Answers Provided to Why Questions and Conditional Probabilities for Free Recall, Cued Recall, Immediate, and 14-Day Delayed Sentence Selection Questionnaires as a Function of Answer Type: Experiment 2

<table>
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<tr>
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<th>Conditional Inadequate Probability</th>
<th>Conditional No Response Probability</th>
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</thead>
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<td>24</td>
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<td>40</td>
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</table>
items about misconceptions and novel items respectively. Inadequate answers accounted for 47% and 40.6% of the responses and no response for 7% and 12.5% of the answers. For facts that addressed misconceptions, items answered adequately were retained better than no response items on cued recall, immediate sentence selection, and 180-day sentence selection tests ($g \geq 4.45, p < .05$). Items answered adequately were also better retained than inadequate items on the sentence-selection task, $t = 10.86, p < .01$; inadequately answered items were remembered better than items with no response on the cued recall and 180-day sentence selection tasks, smaller $g = 3.40, p < .01$. No other significant differences occurred for either recall task, sentence selection, or test delayed variables ($g \leq 1.54, p > .05$). For novel items on the cued recall task, items associated with adequate responses were retained better than items associated with no response ($g = 2.45, p < .05$). There were no other significant differences between the three types of study responses at any retention interval ($g \leq 2.09, p > .05$).

Posttest Interview

Students in both the elaborative-interrogation and reading control groups reported processing the to-be-learned probes according to their assigned study instructions (60.75% and 37.5% of the probes, respectively). On average, reading-control subjects read
each statement 3.30 times. Reported use of alternative processing strategies was low (0% for elaborative-interrogation subjects; 6.25% for reading-control subjects). Elaborative-interrogation and reading-control subjects reported knowing the probe items approximately the same number of times (8.33% and 12.5% of the probes, respectively).

Instructions to read for understanding did not prompt students to use their prior knowledge in a manner that supported the presented facts, or at least, failed to do this to the same extent as elaborative-interrogation instructions. Reading-control subjects were six times more likely to report that they were surprised and didn't know the science information than were elaborative-interrogation subjects (39.58% versus 6.25% of the probes). Reading-control subjects also reported that they did not believe the science information and/or thought the underlying misconception to be true more often than did elaborative-interrogation subjects (14.58% versus 8.33% of the probes).

Students were asked to rate task difficulty for each of the four study passages (1 = very easy, 10 = very hard), and their processing enjoyment for each topic (1 = dislike not like, 10 = liked very much). The mean ratings for task difficulty and study enjoyment are listed in Table 12. Two, 2 (strategy) by 2 (activation) by 4 (passage)
Anovas, with repeated measures on the last variable, were carried out.

For task difficulty, there was a significant main effect for condition \(F(1,75) = 8.80, p<.01\). Elaborative-interrogation subjects perceived their task to be more difficult than did reading control subjects, \(q = 3.52, p<.05\). No other main effects or interactions were significant.

For task enjoyment, there was a significant main effect for passage \(F(3,225) = 6.56, p<.001\). All students enjoyed studying the animal passage more than any other topic, smallest \(q = 4.73, p<.01\). There were no other significant differences in study enjoyment, largest \(q = .59, p>.05\). There were no other significant main effects or interactions.

In summary, the results of this study are in agreement with those of Experiment 1. They justify the conclusions that: (1) Elaborative interrogation was an effective learning strategy, facilitating acquisition of both novel science facts and facts about which learners held inaccurate beliefs. (2) The type of answer given to the elaborative-interrogation why question had little affect on retention. (3) There were recognition but essentially no recall differences associated with fact
Table 12

**Task Difficulty and Study Enjoyment Ratings as a Function of Experimental Condition, Activation, and Passage:**

**Experiment 2**

<table>
<thead>
<tr>
<th>Activators</th>
<th>Nonactivators</th>
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<tr>
<td></td>
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<tr>
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<td>$c^b$</td>
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<td>$p^c$</td>
</tr>
<tr>
<td>$A^d$</td>
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**Condition**

**Task Difficulty**

Elaborative Interrogation

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<th>$p^c$</th>
<th>$A^d$</th>
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<td>5.47</td>
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<td>5.80</td>
<td>5.45</td>
<td>5.40</td>
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<td>1.85</td>
<td>1.79</td>
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Reading Control

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<td>4.87</td>
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<td>5.93</td>
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<tr>
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**Study Enjoyment**

Elaborative Interrogation

<table>
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<tr>
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Reading Control

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<tbody>
<tr>
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<td>2.59</td>
<td>2.88</td>
<td>2.84</td>
<td>3.05</td>
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</table>

**Note.** For task difficulty: 1 = Very Easy, 10 = Very Hard.

**Note.** For study enjoyment: 1 = Did not like, 10 = Liked very much.

**Note.** $s^a$ = Solar System, $c^b$ = Circulatory System

**Note.** $p^c$ = Animals, $A^d$ = Plants.

**Note.** $n = 40$ in each condition.
type. Specifically, novel facts were better recognized than were facts that addressed common misconceptions. (4) Activation instructions, as given in this study, had little affect on retention.

Discussion

The similarity in the findings between Experiments 1 and 2 is striking. Most important was the replication that instructing students to use elaborative interrogation while studying enhanced both recall and recognition relative to instructions to read for understanding. This was true regardless of whether students studied novel facts or facts about which they had prior misconceptions. Elaborative-interrogation learning gains were durable, with retention advantages maintained six months following study. Presumably, elaborative interrogation facilitates learning by prompting students to use their prior knowledge to make inferences and elaborations about study information, thereby creating and strengthening associative links between new and existing information.

Learning gains due to the use of the elaborative-interrogation technique could not be attributed to more retrieval attempts. Elaborative-interrogation and reading-control subjects produced about the same number of incorrect statements and misconceptions during free and cued recall. This is especially noteworthy finding given that instructions to use elaborative-interrogation
encourage learners to focus their attention on information not explicitly stated in study. One might fear that such a process would distract from the acquisition of study materials and encourage retrieval of irrelevant information.

Another encouraging finding was that the quality of answer generated in response to the why question had little impact on retention. As in Experiment 1, there were relatively no differences in the conditional probabilities associated with adequate, inadequate, and no response items, although there was a slight though consistent advantage for items associated with adequate answers (c.f., Pressley et al., 1987; Woloshyn et al., 1990; Wood et al., 1990). Presumably, the process of searching memory for relevant information is sufficient to enhance learning. Thus, even when learners failed to generate a response, or used irrelevant information, learning was enhanced relative to reading for understanding. This is particularly encouraging given the subjects were only able to generate adequate responses for less than half of the study items (i.e., 46%).

Posttest interviews provided additional confirmation that instructions to use elaborative-interrogation focused students' attention on the science facts. Elaborative-interrogation subjects were almost twice as likely to report adherence to processing instructions as were
reading-control subjects, who were more likely to express surprise and/or disbelief about the presented information. Adherence to elaborative-interrogation instructions is especially encouraging given that these subjects perceived their task to be more difficult than did reading-control subjects. This experiment was not the first to reveal that elaborative interrogation is a demanding study strategy (e.g., Pressley et al., 1987; Woloshyn et al., 1990). Despite those demands, however, the rewards associated with using elaborative interrogation appear sufficient to maintain strategy use and enhance retention. On the other hand, merely challenging study information without attempting to resolve discrepancies between prior knowledge and presented information (commonly done by reading-control subjects) does little to facilitate learning.

As in Experiment 1, there were differences in recall and recognition response patterns as a function of fact type. In free recall, subjects were equally likely to retain both novel science facts and facts that underlie common misconceptions. Surprisingly, on the cued recall task, subjects were better able to recall facts addressing misconceptions than novel facts. These results are in general agreement with the findings from Experiment 1 that there were no recall differences associated with the two types of facts, or at least that there was no advantage
for novel items. Thus, subjects apparently do not allow their inaccurate beliefs to override science information at recall.

For the sentence selection questionnaires, students were better able to recognize novel facts than facts that addressed misconceptions. Consistent with Experiment 1 and previous research (e.g., Lipson, 1983), students often allowed their inaccurate beliefs to override scientific information presented in text. However, it is noteworthy that elaborative-interrogation subjects made fewer recognition errors than did their reading control counterparts, demonstrating the effectiveness of the question-answering strategy relative to reading. In addition, when elaborative-interrogation students made correct selections (for both novel facts and facts that addressed common misconceptions), they did so with greater confidence (i.e., they were 100% sure) than did reading-control students. Reading-controls, on the other hand, expressed maximum confidence in their incorrect selections more often than did elaborative-interrogation students. Given that students in the two study conditions showed no differences in their certainty ratings at pretest, these findings further support the potency of elaborative interrogation -- it produced certainty for correct selections and decreased certainty about incorrect selections.
Differences in recall and recognition response patterns can most likely be attributed to the unique demands of the two tasks. Specifically, when students recall information, they must first access information in memory and then make a decision about whether it was presented at study. Although it is unlikely that learners will retrieve conflicting responses, if such items are retrieved, students have the option of not responding. Recognition tasks, on the other hand, present students with a number of competing items (in this case, their incorrect science beliefs), and require them to select a response from among the items. Therefore, the likelihood of making a decision error is greater for recognition tests than for recall tasks. Also, the students were not given explicit instructions to refer to study information when they completed the delayed sentence selection questionnaires.

Regardless of why students make recognition errors, there is a clear need to further develop elaborative-interrogation and/or other strategies so that the occurrence of these errors is reduced. One obvious approach would be to provide subjects with encoding-specific retrieval instructions that promote consistency between study and retrieval. Such instructions are well known to enhance retention (Tulving & Thomson, 1973).

Activation instructions appeared to have no
consistent effect on retention. For free recall, subjects who activated information about irrelevant content (i.e., nonactivators) retained more novel study information than did subjects who activated information about the to-be-learned items (i.e., activators). This finding is contrary to previous demonstrations that having learners activate relevant prior knowledge before study facilitates learning (e.g., Brown et al., 1977; Bransford et al., 1972; Pressley et al., 1987).

When cued recall data were analyzed independent of free recall, activators retained more study information than did nonactivators. This finding was true for both novel facts and study facts about which students possessed misconceptions. This finding is similar to Peeck et al.'s (1982) work where it was found that activation of prior knowledge enhanced acquisition regardless of the consistency between background information and text (i.e., Peeck et al., 1982). For cued recall that incorporated free recall responses, and for the four tests of recognition, there were no effects due to activation instructions.

The inconsistent effects of activation instructions on learning are probably due to methodological shortcomings rather than lack of activation affects per se. Although the subjects did address some of the critical target facts during activation, their review was
by no means exhaustive. On average, students generated eighteen ideas for each activation topic, with only one of these ideas about the target information (i.e., either a verification of the scientific statement or an expression of a common misconception). Because the students tended to elaborate on facts that did not directly correspond to the study information, it is difficult to assess the true contribution of activation instructions on learning and/or what impact these instructions may have in collaboration with processing strategy.

It would be relatively easy to change the nature of the activation instructions so that the students' attention would be focused more on target information. Specifically, a number of activation prompts could be given such that each prompt corresponded to one study statement (e.g., Tell me everything that you know about plants and their food). The use of specific prompts would better guarantee that learners activated prior knowledge (either consistent or inconsistent) about the to-be-learned facts.

General Discussion

The combined findings from these experiments demonstrate that elaborative interrogation is truly an effective learning strategy that can help students acquire difficult science content (i.e., facts that address misconceptions). Furthermore, elaborative-interrogation
learning gains are durable, with superior performance scores maintained up to 6 months following study. Every relevant comparison favored elaborative-interrogation over the demanding reading-control condition (subjects were required to process statements for meaning for the entire time they were presented). In general, these were large effects, with half of the elaborative-interrogation versus reading-control differences greater than one standard deviation in magnitude (i.e., relative to the reading-control standard deviations; Hedges & Olkin, 1985). Specifically, when retention scores were collapsed across text in Experiment 1, four of the eight relevant comparisons were greater than 1 SD (range = .46 SD to 1.44 SD). Similarly, in Experiment 2, 14 of the 28 relevant comparisons were greater than 1 SD (range = .40 SD to 1.88 SD). Another test of strategy effectiveness would be to contrast elaborative-interrogation learning gains with those following "natural study" where students would be instructed to use their normal strategies when processing facts. Such a control would more closely approximate typical study situations than having students continuously read information aloud.

Both researchers and educators are becoming increasingly aware that students often enter the classroom with ideas that are contrary to scientific thought (e.g., Roth, 1990). Students' misconceptions are pervasive and
are resistant to change under normal classroom instruction, with students often allowing their inaccurate beliefs to override text information. Although several techniques have been developed to help students overcome their inaccurate beliefs (i.e., refutation text, conceptual conflict plus accommodation, and anchoring/bridging analogies), many of these strategies are labor intensive for instructors and, thus, relatively impractical in educational settings.

On the other hand, the elaborative-interrogation strategy requires minimal resources from instructors. Using whatever prior knowledge is available to them, students carry out the demanding task of answering the why questions. Even when students do not possess sufficient prior knowledge to answer the why questions adequately, or are unable to express this knowledge, learning is facilitated relative to reading for understanding. This is an important finding inasmuch as students are not always able to generate adequate answers.

Presumably, the process of searching memory for supportive information is sufficient to enhance retention. Attempting to generate a response probably activates a network of facts related to target information (Slamecka & Fevrieski, 1983). Failures to respond are open to alternative interpretations. It is likely that, on at least some occasions, failures to respond reflect a lack
of prior knowledge (e.g., Wood et al., 1990). If elaborative-interrogation learning gains are strictly due to the activation of prior knowledge, learning would not be expected for these no-response items. Alternatively, searching for an explanatory answer may activate a variety of other cognitive mechanisms that enhance learning (e.g., increased arousal/attention, increased meaningful processing of target materials; Tyler et al., 1979).

That elaborative interrogation promotes enhanced processing of study materials is the more likely explanation, inasmuch that retention scores following failures to generate study answers were greater than those associated with reading-for-understanding. This interpretation is also in agreement with recent findings that elaborative interrogation facilitates learning of both familiar and unfamiliar materials (Woloshyn, Pressley, & Schneider, in press).

Elaborative interrogation also is educationally appealing in that the strategy can be used by both individuals and groups. Furthermore, learners do not necessarily require supervision when performing the elaborative-interrogation task. For instance, students probably could be trained to ask themselves “why” questions when reading text information. King (1989) taught grade 9 students to question themselves as they listened to lectures. Although they required a great deal
of training in order to generate and attempt responses to "higher-order" elaboration questions (Bloom, 1956), there were striking memory advantages favoring the self-questioning students relative to untrained controls. More important to the studies reported here, there is evidence that university students continue to use elaborative interrogation when studying novel text following strategy training (Wood & Willoughby, 1991).

There is also reason to suppose that having students generate elaborative-interrogation why responses in small groups (i.e., 2 - 5 persons) would help them to learn new facts. Previous research has shown that students benefit from collaboration with peers and that students who learn the most are those who provide elaborated explanations during group discussion (e.g., Coleman, 1991; Dansereau, 1988; Webb, 1989). Explaining concepts to others requires students to conceptualize materials in new ways, including relating the information to prior knowledge, translating it into more familiar terms, or generating examples related to critical concepts (Bargh & Shul, 1980; King, 1990). In addition, collaborative efforts expose learners to new knowledge and alternative points of view. Verbal interactions are also believed to facilitate the correct use of scientific vocabulary (Champagne et al., 1982).

The research presented here could be extended to evaluate the effectiveness of elaborative interrogation in
group settings, perhaps by using a format similar to King's (1990), in which students are required to first generate their own responses and then share their answers with a small group of peers. The students would be asked to determine the most appropriate responses to the why questions. The process of arriving at group consensus might facilitate the acquisition of both science content and scientifically correct explanations for these facts (i.e., expose learners to new points of view, conceptualize information in a novel manner).

It would be interesting to monitor students' responses to elaborative-interrogation why questions and their subsequent retention scores both before and after normal classroom instruction of critical content. Hopefully, the quality of students' responses would undergo positive change as they were exposed to scientific information. Change would be particularly desirable if students activated irrelevant or scientifically incorrect information, or failed to provide a response to the why question. Presumably, learning would be optimal when students provide both scientifically correct responses and explanations for phenomena (e.g., Champagne et al., 1982).

Alternatively, students could be given passages that contain scientific explanations about the target facts (e.g., a passage about photosynthesis), with instructions to read these passages prior to using elaborative
interrogation. Students would be instructed to use their relevant prior knowledge to provide justification that scientific explanations are appropriate responses to the why questions.

Roth (1990) suggests that while learners often comprehend science information presented in class, and perhaps even acknowledge that this information is inconsistent with their existing beliefs, they do little to promote consistency between the two knowledge sources. At best, students may retain information acquired in class as a separate entity, devoid of meaning and unrelated to everyday life. Such information might only be retrieved for unit tests and other academic activities, with students maintaining their inaccurate beliefs for all other purposes (Champagne et al., 1982; Roth, 1990).

Such encapsulated knowledge is undesirable. True conceptual change can only occur when students adopt scientific information into their everyday understanding of the world (Posner et al., 1982; Champagne et al., 1982). The process of having students provide why answers that integrate everyday knowledge and scientific explanations would require that they devote their time and energy to finding support for both scientific explanations and science facts -- a process already known to facilitate learning.
Appendix A

True Statements
Appendix A

The Sun
1. The sun is a star.
2. The sun is not a living organism -- it is an inanimate object.
3. The sun's surface is not solid.
4. The sun is responsible for the four seasons and changes in the weather.
5. The sun is the most important source of energy for the earth.
6. Much of the sun's solar energy never reaches the earth's surface.
7. The light of the sun is made up of many different colours, including red, orange, yellow, green, blue, and violet.
8. A day in space is blacker than a night on earth.
9. In space, the sun's heat cannot even roast a potato.

Rattlesnakes
1. Many animals and birds, and even other snakes, eat rattlesnakes.
2. Male turkeys can kill full-grown rattlesnakes with their beaks and wings.
3. The rattlesnake's favorite food is field mice.
4. The rattlesnake is not as dangerous and mean as people think.
5. The forked tongue of the rattlesnake helps the animal find out where it is crawling.
6. The forked tongue of the rattlesnakes also helps the animal smell objects.

**Water**

1. Water is as important to people as is air — we cannot live without water.
2. A person can live up to two months without food, but probably could not live longer than a week without water.
3. The average person is made up of about 2/3 water.
4. All living things contain water.
5. Water (water vapour) is even in the air.
6. At high altitudes water boils at a lower temperature than at low altitudes.
7. Water moves in a continuous cycle from the ocean to the air, then to the land, and then back to the ocean.
8. In many parts of the world rain seldom falls.
9. In nature, water always has other materials dissolved in it and therefore, does not exist in a pure form.
10. Water molecules expand (move further apart) when they freeze.
11. Good drinking water is odourless, tasteless, and clear.
Three States of Matter

1. All matter is made of submicroscopic particles or molecules.

2. Molecules are invisible and very small -- so small that they cannot be seen even with a microscope.

3. Solids, liquids and gases are matter and take up space.

4. Other things like heat and light are not matter and do not take up space.

5. Nonmatter does not contain molecules.

6. Depending upon conditions, many substances can exist in either one of three physical states: solids, liquids, or gases.

7. Matter can be changed from solid to liquid, from liquid to gas, from gas to liquid, and from liquid to solid.

8. The nature of substances do not change even when transformed to different states.

9. When water is changed from a liquid to a gas (water vapour) it is still made up of water.

10. All substances continue to exist even though they may become invisible.

11. When a cube of sugar is dissolved in water and you can no longer see the cube, the sugar is still in the water.

12. Molecules always have the same size and temperature.
13. Molecules are constantly moving.
14. Even molecules in solids are never still.
15. There is nothing but empty space between molecules.
16. When a substance is in the gas phase, molecules are far apart and move about freely.
17. Gases can be compressed.
18. The volume of a gas can be changed.
19. When a substance is in a solid phase, molecules are packed together closely and move within a small space.
20. When a substance is in a liquid phase, molecules are loosely clustered and move about more than molecules in solids.
21. Liquids cannot be compressed.
22. When a substance is heated, the molecules move faster and further apart.
23. All substances expand when heated.
25. When a substance is cooled, the molecules move more slowly and move closer together.
26. All substances contract when cooled.
27. Condensation and freezing give off heat.
28. Evaporation and melting absorb heat.
29. When a gas is changed to a solid, heat is given off.
30. When a solid is changed to a gas, heat is absorbed.

Plants
1. Plants can live both on the land and in water.
2. Not all plants have roots, stems, leaves, and flowers.
3. Roots of plants have three functions: to anchor the plant, to absorb water and minerals, and to store food.
4. There are many different types of plant stems, including ones that stand straight up and other that lie along the ground.
5. The stem of the plant carries water and dissolved minerals from the roots to the leaves, and carries food from the leaves to the roots.
6. Most plants are able to produce their own food.
7. Plants do not eat soil and water.
8. Chlorophyll in the cells of plant leaves enables plants to produce their own food.
9. Plants also use light energy from the sun to help them make food.
10. The process of plants producing their own food is called photosynthesis.
11. Plants are able to move their leaves and flowers towards or away from sunlight.
12. Most plants are able to produce asexually -- that is, only one plant is need to create a new plant.
13. Not all new plants come from seeds.
14. Plant seeds are living organisms.
15. New plants can grow from roots, stems, or leaves.
16. Plants help produce the oxygen that people breathe.
Cells

1. All living creatures are made up of cells.
2. Cells are so small that they can only be viewed through a microscope.
3. The cell is the smallest unit of life that can reproduce itself.
4. Cells are composed of many different materials.
5. Cells come from previous existing cells.
6. Some organisms, called protists, have only one cell.
7. Plants and animals are composed of many cells.
8. The continuous task of any living being is to supply its cells with food.
9. Organisms can either make up their own cell food or obtain it from the environment.
10. In order to produce more cells, one cell divides and produces two cells.
11. New cells are needed for growth, to heal damaged cells, and to replace cells that have worn out.
12. Millions of normal cell divisions happen in your body every second.

Earthworms

1. Earthworms are found everywhere on earth except in very dry or cold areas.
2. Earthworms have a variety of colours including reddish-brown, brown, green, and purple.
3. When an earthworm is touched it immediately draws away.
4. Earthworms burrow in the soil.
5. Earthworms' burrowing activities are very important to farmers.
6. The body of an earthworm is covered with a thick gooey substance (mucous) that helps it to breathe.
7. This gooey substance also prevents the earthworm from drying out and helps the animal move through the soil.
8. Each earthworm produces both sperm and eggs.

The Planets
1. Astronomy was the first science of ancient civilizations.
2. At first, men believed the earth was flat.
3. The earth orbits around the sun.
4. The earth is always rotating in circles.
5. We experience daylight when we are on the side of the earth the faces the sun.
6. The interior of the earth is much hotter than its surface temperature.
7. The moon is much smaller than the earth.
8. The moon is an utterly silent place.
9. Planets move around in space.
10. Unlike planets, stars keep a fixed position in space.
11. Stars are really gases in space.
12. Stars are much farther away from the earth than is the sun.
13. The colour of stars varies, ranging from dull red to bluish-white.

Blood
1. Many organisms have no blood.
2. Blood is made of two components: red cells and plasma (a straw-coloured extracellular fluid).
3. Under the microscope, blood looks like red cells in a straw-coloured liquid.
4. The function of the heart is to pump blood.
5. When air enters the body, blood tubes carry air to the heart.
6. Blood also transports nutrients throughout the body.
7. The heart is a double pump, circulating blood both towards and away from itself.
8. The heart pumps both oxygenated and deoxygenated blood.

Animals
1. Some animals can live on the land, in the ocean, and in fresh water.
2. Mammals live both on land and in the water.
3. A spider is an animal.
4. A spider is not an insect.
5. There are more species of insects than there are of
any other class of animal.
6. The bright colours of many dangerous and poisonous insects warn other animals to stay away.
7. People are animals.
8. Some animals have no backbone.
9. There are more animals without backbones than animals with backbones.
10. Most birds have very good eyesight.
11. Some species of birds do not fly.
12. A baby bird will follow the first large object that it sees that moves and makes regular noises.
13. Worker bees dance to tell other bees where there is food.
14. Some animals have developed colouring that lets them blend into their environments.
15. The brown and white spots of a baby deer help it hide in the forest.
16. Adult deer do not need to have white spots on their fur for protection.

**Genetics**
1. Environmentally induced factors cannot be transmitted to offspring.
2. A female dog who limped as a result of an accident will not give birth to a lame puppy.
3. Even if the tails of puppies were repeatedly shortened over several generations, stubby tails would not be
acquired genetically.
4. The mother and father contribute equally to the genetic make-up of their offspring.
5. Both gene mutation and development deficits can cause variation in an individual.
6. A gene cannot be dominant in one offspring and recessive in another.

**Frogs**
1. Frogs hibernate during the winter.
2. Baby frogs are born with feathery gills and a tail.
3. Baby frogs usually dwell in the water.
4. Only when a baby frog is three months old is it able to come out of the water and onto the land.
5. Baby frogs breathe with gills.
6. Adult frogs normally breathe with lungs.
7. The hind legs of a frog only begin to develop when the animal is two months old.
8. Frogs swallow their food whole.

**Rocks**
1. Rocks are composed of different types of minerals.
2. Crystals are formed when molten rock cools and begins to soften.
3. Large crystals mean that molten rock cooling has happened slowly.
4. Small, fine crystals are often found by the sea.
5. The Rocky Mountains are composed mainly of sedimentary rocks that were once flat and covered with water.
6. Sedimentary rocks can be formed from the shells and skeletons of animals and from plant remains.
7. The shapes of organisms are sometimes preserved in rocks as fossils.
8. Coal, natural gas, and oil are fossil fuels.

AIDS

1. AIDS is a medical condition in which your body cannot fight off diseases.
2. AIDS is a relatively new disease.
3. AIDS is caused by a virus.
4. Stress does not cause AIDS.
5. A person cannot get AIDS by touching someone with the disease.
6. All gay men do not have AIDS.
7. Anybody can get AIDS.
8. AIDS cannot be cured, even if treated early.
9. AIDS cannot be spread by using someone's personal belongings like a comb or hairbrush.
10. AIDS is caused by a different virus than the one that causes VD.
11. A person cannot contract AIDS by just being around someone who has the disease.
12. Having sex with someone who has AIDS is one way of
contracting the disease.

13. If a pregnant women has AIDS, there is a chance this may harm her unborn baby.

14. Most people who get AIDS usually die from the disease.

15. Using a condom during sex can lower the risk of getting AIDS.

16. A person cannot get AIDS by shaking hands with someone who has the disease.

17. Receiving a blood transfusion with infected blood can give a person AIDS.

18. A person can get AIDS by sharing a needle with a drug user who has the disease.

19. AIDS is a life threatening disease.

20. People who have AIDS usually have lots of other diseases as a result of AIDS.

21. People who get AIDS are not very likely to become crippled.

22. People who get AIDS are more likely to get cancer than are people who do not have AIDS.

23. All gay women do not have AIDS.


25. It is not easy to detect a person with AIDS.

26. A person who is AIDS infected may not have any disease symptoms for a long time.

27. Some people who are exposed to the AIDS virus may
never get the disease.
28. A person cannot get AIDS from attending school with a student who has AIDS.
29. It is safe for people with AIDS to work near children.
30. A person cannot get AIDS by using the same swimming pool with someone who has the disease.
Appendix B

False Statements
Appendix B

The Sun

1. The sun is not a star.
2. The sun is a living organism -- it is an animate object.
3. The sun's surface is solid.
4. The sun has little to do with the four seasons and changes in the weather.
5. The sun is not considered to be the most important source of energy for the earth.
6. Almost all of the sun's solar energy reaches the earth's surface.
7. The light of the sun is made up of only a few colours, mostly yellow and orange.
8. A day in space is lighter than a night on earth.
9. In space, the sun's heat can easily roast a potato.

Rattlesnakes

1. There are not many animals and birds, or even other snakes, that will eat rattlesnakes.
2. Even with their strong beaks and wings, male turkeys cannot kill full-grown rattlesnakes.
3. Rattlesnakes strongly dislike field mice as a source of food.
4. The rattlesnake is very dangerous and mean.
5. The forked tongue of the rattlesnake is of little use to the rattlesnake.
6. The rattlesnake smells objects with its nostrils.

Water
1. Air is more important to people than is water -- people can live without water.
2. A person can live up to two months without food and a lot longer without water.
3. A average person is made up of very little water, less than 1/3.
4. Not all living things contain water.
5. One place that water does not exist is in the air.
6. At high altitudes water boils at higher temperatures than at low altitudes.
7. Water moves only in a one direction from the air to the land.
8. Rain falls abundantly in every part of the world.
9. In nature, water can exist in a pure form with no other materials dissolved in it.
10. The distance between water molecules does not change when water is frozen.
11. Good drinking water has an odour, some taste, and a slight colour.

Three States of Matter
1. Some forms of matter do not have particles or molecules.
2. Although molecules are fairly small they are still
visible and can be seen with a microscope.

3. Gases are not matter and therefore, do not take up space.

4. Heat and light are matter and take up space.

5. Some nonmatter also contains molecules.

6. Many substances can exist in only one of three physical states: solids, liquids, or gases.

7. It is very difficult to change matter from solid to liquid, from liquid to gas, from gas to liquid, or from liquid to solid.

8. When substances are transformed to different states.

9. When water is changed from a liquid to a gas (water vapour) the make-up of the water changes from its true form.

10. All substances cease to exist when they become invisible.

11. When a cube of sugar is dissolved in the water and you can no longer see the cube, the sugar no longer exists in the water.

12. Molecules can change in size and temperature.

13. Molecules are mostly motionless.

14. Molecules in solids are always still.

15. Air mostly fills in the spaces between molecules.

16. When a substance is in the gas phase, molecules are close and do not move about.

17. Gases cannot be compressed.
18. The volume of a gas cannot be changed.
19. When a substance is in a solid phase, molecules are packed together closely and do not move at all.
20. When a substance is in a liquid phase, molecules are still clustered fairly closely together and do not move.
21. Liquids can be compressed.
22. Heating a substance does not change the rate at which molecules move or their distance from one another.
23. Not all substances expand when heated.
25. Cooling a substance does not change the rate at which molecules move or their distance from one another.
26. Not all substances contract when cooled.
27. Condensation and freezing absorb heat.
28. Evaporation and melting give off heat.
29. When a gas is changed to a solid, heat is absorbed.
30. When a solid is changed to a gas, heat is given off.

**Plants**
1. Plants can only live in the water.
2. All plants have roots, stems, leaves, and flowers.
3. The only function of the roots is to anchor the plant into the soil.
4. There is only one type of plant stem, those that stand straight up.
5. The stem of the plant does not play a large function
in carrying water and dissolved minerals from the roots to the leaves, or carrying food from the leaves to the roots.

6. Plants are not able to produce their own food.
7. Plants eat soil and water.
8. Chlorophyll in the cells of plant leaves helps plants to digest soil and water.
9. Plants use light energy from the sun to help them stay warm.
10. The process of plants eating soil and water is called photosynthesis.
11. Plants are not able to move their leaves and flowers.
12. Most plants reproduce sexually -- that is, two plants are needed to create a new plant.
13. All new plants come from seeds.
14. Plant seeds are not living organisms.
15. New plants cannot grow from a roots, stems, or leaves.
16. Plants use up the oxygen that people breathe.

**Cells**

1. Not all living creatures are made up of cells.
2. Cells are big enough that they can be seen without a microscope.
3. The cell is not considered a unit of life and cannot reproduce itself.
4. Cells are only composed of one type of material.
5. Cells are only produced once in a person's life when
they are born.
6. There are no living organisms that have only one cell.
7. Plants and animals are composed of only a few cells.
8. Living beings do not need to worry about supplying their cells with food.
9. Organisms cannot make up their own cell food or obtain it from the environment.
10. In order to produce more cells, two cells merge to produce a new cell.
11. New cells are rarely needed for growth, to heal damaged cells, or to replace cells that have worn out.
12. Very few cell divisions occur in your body.

**Earthworms**

1. Earthworms are only found in very dry or very cold areas of the earth.
2. Earthworms are not very colourful, being only brown in colour.
3. When an earthworm is touched it immediately spread its entire length.
4. Earthworms lie on the top of the soil.
5. Farmers consider earthworms to be pests.
6. The body of an earthworm is dry and smooth so that it can breathe better.
7. The dry and smooth body of the earthworm also prevents it from drying out and helps the animal move through
the soil.

8. Each earthworm produces either sperm or eggs but not both.

Planets

1. Astronomy was one of the last sciences of modern civilization.
2. At first, man believed the earth was round.
3. The sun orbits around the earth.
4. The earth is in a fixed position.
5. We experience daylight when the sun is on the side of the same side of the earth that we are.
6. The interior of the earth is much cooler than its surface temperature.
7. The moon is much larger than the earth.
8. The moon is a noisy place.
9. Planets remain in a constant position in space.
10. Unlike planets, stars move around in space.
11. Stars are really solid masses in space.
12. The sun is much farther away from the earth than are the stars.
13. Stars do not vary in their colour being yelowish-white in colour.

Blood

1. All organisms have blood.
2. Blood is made of only one component: red cells.
3. Under the microscope, blood looks like a bunch of red cells clustered closely together.
4. The functions of the heart include cleaning, filtering, making, and storing blood.
5. When air enters the body, air tubes from the lungs take the air to the heart.
6. Blood does not help transport nutrients throughout the body.
7. The heart is a single pump, pumping blood from itself to the body.
8. The heart only pumps oxygenated blood.

**Animals**

1. Animals can only live in one of three habitats: on the land, or in the ocean, or in fresh water.
2. Mammals live in the water.
3. A spider is not an animal.
4. A spider is not an insect.
5. There are less species of insects that there are any other class of animals.
6. The bright colours of many dangerous and poisonous insects draw other animals closer and help the insect kill them.
7. People are not animals.
8. All animals have a backbone.
9. There are more animals with backbones than there are animals without backbones.
10. Most birds have very poor eyesight.
11. All species of birds fly.
12. A baby bird hatches will only follow the first bigger bird that it sees that makes regular noises.
13. Worker bees buzz to tell other bees where there is food.
14. Not many animals have developed colouring that lets them blend into their environments.
15. The brown and white spots of a baby deer make it obvious prey for larger animals in the forest.
16. When a baby deer becomes an adult, it loses its white spots and is better able to hide in the forest.

Genetics

1. Environmentally induced factors can be transmitted to offspring.
2. A female dog who limps as a result of an accident, will likely given birth to a lame puppy.
3. If the tails of puppies were repeatedly shortened over several generations, stubby tails would be acquired genetically.
4. The mother contributes more to the genetic make-up of her offspring than does the father.
5. Variation in an individual is caused by developmental deficits only.
6. A gene can be dominant in one offspring and recessive in another.
**Frogs**

1. Frogs go to warmer climates in the winter.
2. When baby frogs are born they look like a miniature adult frog.
3. Baby frogs usually dwell on land.
4. Only when a baby frog is three months old is it able to come off the land and into the water.
5. Baby frogs breathe with lungs.
6. Adult frogs normally breathe with gills.
7. The hind legs of a baby frog are fully developed when the frog is hatched.
8. Frogs swallow their food in little pieces.

**Rocks**

1. Rocks are composed of only a few types of minerals.
2. Crystals are formed when molten rock heat and begin to harden.
3. Large crystals mean that molten rocks heated very quickly.
4. Small, fine crystals are often found in the mountains.
5. The Rocky Mountains are the largest mountains in the world.
6. Sedimentary rocks cannot be formed from the shells or skeletons of animals nor from plant remains.
7. The shapes of organisms are rarely preserved in rocks.
8. Coal, natural gas, and oil are not fossil fuels.
AIDS
1. AIDS is a medical condition that does not effect your body's ability to fight off diseases.
2. AIDS is an old disease and has been around for a long time.
3. AIDS is not caused by a virus.
4. Stress can cause AIDS.
5. A person can get AIDS by touching someone with the disease.
6. All gay men have AIDS.
7. Just certain people, like gays, can get AIDS.
8. AIDS can be cured, especially if treated early.
9. AIDS can be spread by using someone's personal belongings like a comb or hairbrush.
10. AIDS is caused by the same virus than the one that causes VD.
11. A person can contract AIDS by being around someone who has the disease.
12. Having sex with someone who has AIDS is an unlikely way of contracting the disease.
13. If a pregnant women has AIDS, there is little chance that this will harm her unborn baby.
14. Most people who get AIDS will not die from the disease.
15. Using a condom during sex will do little to lower the risk of getting AIDS.
16. A person can get AIDS by shaking hands with someone who has the disease.
17. Receiving a blood transfusion with infected blood cannot give a person AIDS.
18. A person cannot get AIDS by sharing a needle with a drug user who has the disease.
19. AIDS is not considered a life threatening disease.
20. People who have AIDS rarely contract other diseases as a result of AIDS.
21. People who get AIDS are likely to become crippled.
22. People who get AIDS are no more likely than people who do not have AIDS to develop cancer.
23. All gay women have AIDS.
24. A person can avoid contracting AIDS by exercising regularly.
25. It is very easy to detect a person with AIDS.
26. Very shortly after a person becomes AIDS infected, he/she will show disease symptoms.
27. All people exposed to the AIDS virus will get the disease.
28. A person can get AIDS by attending school with a student who has AIDS.
29. It is unsafe for people with AIDS to work near children.
30. A person can get AIDS by using the same swimming pool with someone who has the disease.
Appendix C

Pilot Sentence Selection Questionnaires
Appendix C

Sentence Selection Questionnaire One

1. The sun is a star.
2. The sun is not a star.

The correct sentence is number ________

I am 100% SURE 50% SURE 100% UNSURE

____________________________________________________________________

1. Substances expand (move further apart) when heated.
2. Substances do not expand (move further apart) when heated.

The correct sentence is number ________

I am 100% SURE 50% SURE 100% UNSURE

____________________________________________________________________

1. Planets do not move around in space.
2. Planets move around in space.

The correct sentence is number ________

I am 100% SURE 50% SURE 100% UNSURE

____________________________________________________________________

1. Coal, natural gas, and oil are fossil fuels.
2. Coal, natural gas, and oil are not fossil fuels.

The correct sentence is number ________

I am 100% SURE 50% SURE 100% UNSURE
1. The size and temperature of molecules change.
2. The size and temperature of molecules do not change.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

____________________________________________

1. Earthworms come in many colours including reddish-brown, brown, green, and purple.
2. Earthworms do not come in many colours, only reddish-brown and brown.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

____________________________________________

1. Condensation and freezing take in (absorb) heat.
2. Condensation and freezing give off heat.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

____________________________________________

1. Baby frogs breathe with gills.
2. Baby frogs breathe with lungs.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

____________________________________________
1. Water is not alive.
2. Water is alive.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

----

1. The light of the sun is made up of every different colour including red, orange, yellow, green, blue, and violet.
2. The light of the sun is made up of only a few colours, mostly red and orange.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

----

1. When a gas is change to a solid, heat is taken in (absorbed).
2. When a gas is changed to a solid, heat is given off.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

----

1. Water exists in the air.
2. Water does not exist in the air.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

---
1. Blood is made of only one component: red cells.
2. Blood is made of two components: red cells and plasma (a straw-coloured fluid).

The correct sentence is number ______

I am 100% SURE     50% SURE     100% UNSURE

____________________________________________________________________

____________________________________________________________________

1. Molecules of gas stay close together and do not move about.
2. Molecules of gas stay far apart and move about.

The correct sentence is number ______

I am 100% SURE     50% SURE     100% UNSURE

____________________________________________________________________

____________________________________________________________________

1. Rocks are composed of many different minerals.
2. Rocks are composed of only a few minerals.

The correct sentence is number ______

I am 100% SURE     50% SURE     100% UNSURE

____________________________________________________________________

____________________________________________________________________

1. Plants make some of the oxygen that people breathe.
2. Plants use some of the oxygen that people breathe.

The correct sentence is number ______

I am 100% SURE     50% SURE     100% UNSURE

____________________________________________________________________

____________________________________________________________________
1. A spider is an animal.
2. A spider is not an animal.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE

1. The thin and dry body of the earthworm helps the animal breathe.
2. The thick and gooey (mucous) body of the earthworm helps the animal breathe.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE

1. Plants get their food from the soil.
2. Plants do not get their food from the soil.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE

1. Male turkeys can kill full grown rattlesnakes with their strong beaks and wings.
2. Male turkeys cannot kill full grown rattlesnakes, even with their strong breaks and wings.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE
1. There is not water in rocks.
2. There is water in rocks.

The correct sentence is number ______

I am 100% SURE     50% SURE     100% UNSURE

1. In nature, water has no other materials dissolved in it and exists in a pure form.
2. In nature, water has other materials dissolved in it and does not exist in a pure form.

The correct sentence is number ______

I am 100% SURE     50% SURE     100% UNSURE

1. Blood helps transport nutrients (food that helps growth) throughout the body.
2. Blood does not help transport nutrients (food that helps growth) throughout the body.

The correct sentence is number ______

I am 100% SURE     50% SURE     100% UNSURE

1. People are not animals.
2. People are animals.

The correct sentence is number ______

I am 100% SURE     50% SURE     100% UNSURE
1. Oxygen is not the same as air.
2. Oxygen is the same as air.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

---

1. In space, the sun's heat can roast a potato.
2. In space, the sun's heat cannot roast a potato.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

---

1. Plants can live both on the land and in the water.
2. Plants can live on the land only.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

---

1. Stars can have many different colours, ranging from dull red to bluish-white.
2. Stars do not have many different colours, being yellowish-white.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE
1. Molecules in liquids are clustered together loosely and move about more than molecules in solids.
2. Molecules in liquids are clustered together tightly and do not move.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE

1. Many mountains were flat and covered with water.
2. All mountains were tall and above the water.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE

1. Molecules are small, but they can be seen with a microscope.
2. Molecules are small, so small that they cannot be seen with a microscope.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE

1. Cells are composed of one type of material.
2. Cells are composed of many different types of materials.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE
1. All birds do not fly.
2. All birds fly.

The correct sentence is number ______
I am 100% SURE  50% SURE  100% UNSURE

____________________________

1. Respiration is the same as breathing.
2. Respiration is not the same as breathing.

The correct sentence is number ______
I am 100% SURE  50% SURE  100% UNSURE

____________________________

1. Solids expand (get bigger) when heated.
2. Solids do not expand (get bigger) when heated.

The correct sentence is number ______
I am 100% SURE  50% SURE  100% UNSURE

____________________________
Sentence Selection Questionnaire: Two

1. The rattlesnake is very dangerous and mean.
2. The rattlesnake is not as dangerous and mean as people think.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE

_________________________________________________________________

1. The stem of the plant carries food from the leaves to the roots.
2. The stem of the plant does not carry food from the leaves to the roots.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE

_________________________________________________________________

1. The heart has one function, pumping blood.
2. The heart has several functions including pumping, making, and storing blood.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE

_________________________________________________________________

1. The sun is alive.
2. The sun is not alive.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE
1. All insects have wings.
2. Not all insects have wings.

The correct sentence is number ______
I am 100% SURE  50% SURE  100% UNSURE

1. The interior (inside) of the earth is much cooler than its surface temperature.
2. The interior (inside) of the earth is much hotter than its surface temperature.

The correct sentence is number ______
I am 100% SURE  50% SURE  100% UNSURE

1. All living things contain water.
2. Not all living things contain water.

The correct sentence is number ______
I am 100% SURE  50% SURE  100% UNSURE

1. New plants can only grow from seeds.
2. New plants can grow from roots, stems, or leaves.

The correct sentence is number ______
I am 100% SURE  50% SURE  100% UNSURE
1. The bright colours of many dangerous and poisonous insects attract other animals closer and helps the insect kill them.
2. The bright colours of many dangerous and poisonous insects warn other animals to stay away.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

1. Living beings do not need to supply their cells with food.
2. Living beings need to supply their cells with food.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

1. Molecules in solids move.
2. Molecules in solids do not move.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

1. The brown and white spots of a baby deer make it obvious prey for larger animals in the forest.
2. The brown and white spots of a baby deer help it hide from larger animals in the forest.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE
1. In the mountains, water begins to boil at a higher temperature than at ground level.
2. In the mountains, water begins to boil at a lower temperature than at ground level.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE

1. All matter is made of particles or molecules.
2. Not all matter is made of particles or molecules.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE

1. All new plants come from seeds.
2. Not all new plants come from seeds.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE

1. Some organisms have no blood.
2. All organisms have blood.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE
1. Matter can be changed from gas to liquid.
2. Matter cannot be changed from gas to liquid.

The correct sentence is number ______

I am 100% SURE         50% SURE         100% UNSURE

1. A spider is an insect.
2. A spider is not an insect.

The correct sentence is number ______

I am 100% SURE         50% SURE         100% UNSURE

1. Many animals and birds eat rattlesnakes.
2. Not many animals and birds eat rattlesnakes.

The correct sentence is number ______

I am 100% SURE         50% SURE         100% UNSURE

1. The hind legs of a frog begin to develop when the animal is two months.
2. The hind legs of a frog are fully developed when the animal is hatched.

The correct sentence is number ______

I am 100% SURE         50% SURE         100% UNSURE
1. All plants have roots.
2. Not all plants have roots.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

1. Plants and animals are composed of a small number of cells.
2. Plants and animals are composed of a large number of cells.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

1. Water molecules expand (move further apart) when water is frozen.
2. Water molecules do not expand (move further apart) when water is frozen.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

1. All animals have backbones.
2. Not all animals have backbones.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE
1. The forked tongue of the rattlesnake helps the animal find out where it is crawling.
2. The forked tongue of the rattlesnake does not help the animal find out where it is crawling.

The correct sentence is number _____

I am 100% SURE  50% SURE  100% UNSURE

1. New cells are needed for growth.
2. New cells are not needed for growth.

The correct sentence is number _____

I am 100% SURE  50% SURE  100% UNSURE

1. The volume of a gas cannot be changed.
2. The volume of a gas can be changed.

The correct sentence is number _____

I am 100% SURE  50% SURE  100% UNSURE

1. Air tubes carry air to the heart.
2. Blood tubes carry air to the heart.

The correct sentence is number _____

I am 100% SURE  50% SURE  100% UNSURE
1. Each earthworm produces both sperm and eggs.
2. Each earthworm produces either sperm or eggs, but not both.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

1. A large crystal means that molten rock has heated very quickly.
2. A large crystal means that molten rock has cooled slowly.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

1. Substances that are not matter contain molecules.
2. Substances that are not matter do not contain molecules.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

1. Plants eat soil.
2. Plants do not eat soil.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE
1. Heat and light do not take up space.
2. Heat and light take up space.

The correct sentence is number _____

I am 100% SURE  50% SURE  100% UNSURE

__________________________________________________________________________

1. Under the microscope, blood looks like a red liquid.
2. Under the microscope, blood does not look like a red liquid.

The correct sentence is number _____

I am 100% SURE  50% SURE  100% UNSURE

__________________________________________________________________________

1. A boy is an animal.
2. A boy is not an animal.

The correct sentence is number _____

I am 100% SURE  50% SURE  100% UNSURE

__________________________________________________________________________
**Sentence Selection Questionnaire: Three**

1. Plants use light energy from the sun to help them stay warm.  
2. Plants use light energy from the sun to help them make food.

The correct sentence is number ______

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1. Almost all the sun's solar energy reaches the earth's surface.  
2. Much of the sun's solar energy never reaches the earth's surface.

The correct sentence is number ______

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1. Evaporation and melting take in (absorb) heat.  
2. Evaporation and melting give off heat.

The correct sentence is number ______

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1. Relative to planets, stars move around in space.  
2. Relative to planets, stars do not move around in space.

The correct sentence is number ______

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1. Substances continue to exist when they become invisible.
2. Substances stop to exist when they become invisible.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

1. Gases are matter.
2. Gases are not matter.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

1. Cells are alive.
2. Cells are not alive.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

1. A baby bird will follow the first large object that moves and makes noise.
2. A baby bird will only follow the first bigger bird that moves and makes noise.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE
1. Some organisms called protists have only one cell.
2. All organisms, including protists, have more than one cell.

The correct sentence is number ______
I am 100% SURE      50% SURE      100% UNSURE

1. Most birds have very poor eyesight.
2. Most birds have very good eyesight.

The correct sentence is number ______
I am 100% SURE      50% SURE      100% UNSURE

1. The earth is in a fixed position -- it never moves.
2. The earth is always rotating in circles -- it is always moving.

The correct sentence is number ______
I am 100% SURE      50% SURE      100% UNSURE

1. The heart pumps both blood with oxygen and blood without oxygen.
2. The heart only pumps blood with oxygen.

The correct sentence is number ______
I am 100% SURE      50% SURE      100% UNSURE
1. In North America baby frogs dwell on land.
2. In North America baby frogs dwell in the water.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

______________________________

1. Matter cannot be changed from solid to liquid.
2. Matter can be changed from solid to liquid.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

______________________________

1. Some animals can live in all three habitats: on the land, in salt water, and in fresh water.
2. Animals can live in only one of three habitats: on the land, in salt water, or in fresh water.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

______________________________

1. Very few cell divisions happen in your body during your lifetime.
2. Millions of cell divisions happen in your body every second.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

______________________________
1. Adult frogs breathe with lungs.
2. Adult frogs breathe with gills.

The correct sentence is number ______
I am 100% SURE   50% SURE   100% UNSURE

1. There is no air in rocks.
2. There is air in rocks.

The correct sentence is number ______
I am 100% SURE   50% SURE   100% UNSURE

1. When a substance is heated, the molecules move faster and further apart.
2. When a substance is heated, the molecules move slower and closer together.

The correct sentence is number ______
I am 100% SURE   50% SURE   100% UNSURE

1. When water is changed to a gas, the gas is still made up of water.
2. When water is changed to a gas, the gas is not longer made up of water.

The correct sentence is number ______
I am 100% SURE   50% SURE   100% UNSURE
1. The shapes of organisms are rarely preserved in rocks.
2. The shapes of organisms are often preserved in rocks.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE

_________________________________________________________________________

1. Gases take up space.
2. Gases do not take up space.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE

_________________________________________________________________________

1. Plant stems can grow both above the ground and below the ground.
2. Plant stems can only grow above the ground.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE

_________________________________________________________________________

1. When a baby deer becomes an adult, it loses its white spots and is better able to hide in the forest.
2. When a baby deer becomes an adult, it loses its white spots and no longer needs to hide in the forest.

The correct sentence is number ______

I am 100% SURE 50% SURE 100% UNSURE

_________________________________________________________________________
1. Water moves in a cycle from the ocean to the air, to the land, and back to the ocean.
2. Water moves in one direction from the air to the land.

The correct sentence is number ______
I am 100% SURE      50% SURE      100% UNSURE

1. Plant seeds are living organisms.
2. Plant seeds are not living organisms.

The correct sentence is number ______
I am 100% SURE      50% SURE      100% UNSURE

1. There are less species of insects than any other class of animal.
2. There are more species of insects than any other class of animal.

The correct sentence is number ______
I am 100% SURE      50% SURE      100% UNSURE

1. The sun is responsible for the four seasons and changes in the weather.
2. The sun is not responsible for the four seasons and changes in the weather.

The correct sentence is number ______
I am 100% SURE      50% SURE      100% UNSURE
1. The moon is a silent place.
2. The moon is a noisy place.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

1. Matter cannot be changed from liquid to solid.
2. Matter can be changed from liquid to solid.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

1. Substances do not contract (become smaller) when cooled.
2. Substances contract (become smaller) when cooled.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE

1. The heart pumps blood towards and away from itself.
2. The heart pumps blood away from itself to the body.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE
1. A person can live up to two months without water, but probably could not live longer than a week without food.
2. A person can live up to two months without food, but probably could not live longer than a week without water.

The correct sentence is number _____

I am 100% SURE  50% SURE  100% UNSURE

-----------------------------

1. Molecules are always moving.
2. Molecules are not always moving.

The correct sentence is number _____

I am 100% SURE  50% SURE  100% UNSURE

-----------------------------

1. Heat and temperature are the same thing.
2. Heat and temperature are not the same thing.

The correct sentence is number _____

I am 100% SURE  50% SURE  100% UNSURE
Sentence Selection Questionnaire: Four

1. When a cube of sugar is dissolved in water, the sugar still exists in the water.
2. When a cube of sugar is dissolved in water, the sugar no longer exists in the water.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE


1. Earthworms are only found in very dry or very cold areas of the earth.
2. Earthworms are found everywhere on earth except in very dry or cold areas.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE


1. Only when a baby frog is three months old is it able to leave the land and go into the water.
2. Only when a baby frog is three months old is it able to leave the water and go on the land.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE


1. Plants are able to move their leaves and flowers.
2. Plants are not able to move their leaves and flowers.

The correct sentence is number ______

I am 100% SURE  50% SURE  100% UNSURE
1. There are more animals without backbones than animals with backbones.
2. There are more animals with backbones than there are animals without backbones.

The correct sentence is number ______

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1. Rocks cannot be formed from the shells and skeletons of animals.
2. Rocks can be formed from the shells and skeletons of animals.

The correct sentence is number ______

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1. The sun is much farther away from the earth than are the stars.
2. The stars are much farther away from the earth than is the sun.

The correct sentence is number ______

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1. Molecules of gases can be compressed (moved closer together).
2. Molecules of gases cannot be compressed (moved closer together).

The correct sentence is number ______

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1. New cells are produced from existing cells.
2. New cells are produced only once when a person is born.

The correct sentence is number ______
I am 100% SURE  50% SURE  100% UNSURE

1. Plant stems stand straight up.
2. Not all plant stems stand straight up.

The correct sentence is number ______
I am 100% SURE  50% SURE  100% UNSURE

1. The tomato is a fruit.
2. The tomato is a vegetable.

The correct sentence is number ______
I am 100% SURE  50% SURE  100% UNSURE

1. The earth orbits around the sun.
2. The sun orbits around the earth.

The correct sentence is number ______
I am 100% SURE  50% SURE  100% UNSURE
1. Worker bees buzz to tell other bees where there is food.
2. Worker bees dance to tell other bees where there is food.

The correct sentence is number ______
   I am 100% SURE        50% SURE        100% UNSURE

1. When a solid is changed to a gas, heat is taken in (absorbed).
2. When a solid is changed to a gas, heat is given off.

The correct sentence is number ______
   I am 100% SURE        50% SURE        100% UNSURE

1. A day in space is lighter than a night on earth.
2. A day in space is darker than a night on earth.

The correct sentence is number ______
   I am 100% SURE        50% SURE        100% UNSURE

1. Air fills in all the empty spaces between molecules.
2. Nothing fills in the empty spaces between molecules.

The correct sentence is number ______
   I am 100% SURE        50% SURE        100% UNSURE
1. Earthworms' burrowing activities are very helpful to farmers.
2. Earthworms' burrowing activities are very harmful to farmers.

The correct sentence is number _______

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1. Heat and light are matter.
2. Heat and light are not matter.

The correct sentence is number _______

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1. The moon is larger than the earth.
2. The moon is smaller than the earth.

The correct sentence is number _______

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1. Frogs swallow their food whole.
2. Frogs swallow their food in little pieces.

The correct sentence is number _______

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1. Under the microscope blood looks like a bunch of red cells in a straw-colored liquid.
2. Under the microscope blood looks like a bunch of red cells.

The correct sentence is number ________

I am 100% SURE  50% SURE  100% UNSURE

1. Molecules of liquids can be compressed (moved closer together).
2. Molecules of liquids cannot be compressed (moved closer together).

The correct sentence is number ________

I am 100% SURE  50% SURE  100% UNSURE

1. Stars are gases in space.
2. Stars are not gases in space.

The correct sentence is number ________

I am 100% SURE  50% SURE  100% UNSURE

1. When a substance is a solid, molecules are packed together closely and move very little.
2. When a substance is a solid, molecules are packed far apart and move freely.

The correct sentence is number ________

I am 100% SURE  50% SURE  100% UNSURE
1. The heart is a single pump.
2. The heart is a double pump.

The correct sentence is number _______.

I am 100% SURE   50% SURE   100% UNSURE

1. Two cells can merge (come together) to produce a new cell.
2. One cell can divide to produce a new cell.

The correct sentence is number _______.

I am 100% SURE   50% SURE   100% UNSURE

1. Chlorophyll helps plants produce their own food.
2. Chlorophyll helps plants digest soil.

The correct sentence is number _______.

I am 100% SURE   50% SURE   100% UNSURE

1. The sun's surface is solid.
2. The sun's surface is not solid.

The correct sentence is number _______.

I am 100% SURE   50% SURE   100% UNSURE

1. Small fine crystals are often found by the mountains.
2. Small fine crystals are often found by the sea.

The correct sentence is number _______.

I am 100% SURE   50% SURE   100% UNSURE
1. Frogs hibernate during the winter.
2. Frogs go to warmer climates during the winter.

The correct sentence is number ________

I am 100% SURE        50% SURE        100% UNSURE

____________________

1. The nature of substances changes when they are transformed to different states of matter.
2. The nature of substances does not change when they are transformed to different states of matter.

The correct sentence is number ________

I am 100% SURE        50% SURE        100% UNSURE

____________________

1. Crystals are formed when molten rock cools and begins to soften.
2. Crystals are formed when molten rock heats and begins to harden.

The correct sentence is number ________

I am 100% SURE        50% SURE        100% UNSURE

____________________

1. When a substance is cooled, the rate at which the molecules move do not change.
2. When a substance is cooled, the molecules move more slowly.

The correct sentence is number ________

I am 100% SURE        50% SURE        100% UNSURE

____________________
1. Water molecules attract each other and form clusters.
2. Water molecules do not attract each other and form clusters.

The correct sentence is number _____

I am 100% SURE  50% SURE  100% UNSURE

1. Plants always need light.
2. Plants do not always need light.

The correct sentence is number _____

I am 100% SURE  50% SURE  100% UNSURE
Appendix D

Practice Sentences and To-Be-Learned Sentences:

Experiment 1
Appendix D

Study Order: 1

Practice Sentences:

1. The blue whale only eats for about three months of the year.
2. The swift fox sleeps all day, although some people think that the fox is awake during the day.
3. Baby deer do not need to hide in the forest when they become adults.
4. Although some people think that a spider is an insect, a spider is not an insect.

To-Be-Learned Sentences:

1. Plants do not always need light.
2. The soil provides plants with oxygen, although some people think that plants get oxygen from the sky.
3. Not all plants have roots.
4. Although some people think that the most important reason why plants need water is to drink, it is to cool off their leaves.
5. Plants do not get food from the soil, although some people think that they get food from the ground.
6. All human food originally comes from green plants.
7. Maple keys and milkweed pods are fruits.
8. Although some people think that new plants can grow
from seeds only, they can grow from roots, stems, and leaves.

9. Stars are gases in space.

10. Although some people think that the largest volcano is on earth, it is on the planet Mars.

11. The light of the sun is made of every different colour including red, yellow, blue, and violet.

12. Although some people think that oxygen and air are the same, they are not the same.

13. The size of a star changes.

14. In space, the sun's heat cannot even roast a potato, although some people think that it can.

15. Moon soil is made up of small pieces of rock and glass, although some people think that it is only made up of rock.

16. The distance between the earth and the moon changes everyday.

17. The left side of the heart pumps blood to the body.

18. Some living things have only one cell, although some people think that all living things have more than one cell.

19. Respiration is not the same as breathing.

20. There are four main types of blood, although some people think that there is only one type.

21. Although some people think that the heart only pumps blood with oxygen, it pumps blood with oxygen and
blood without oxygen.

22. New red blood cells are needed about every four months.

23. Although some people do not think that pus is blood cells, pus is white blood cells that have died.

24. The only function of the heart is to pump blood.

25. The larger an animal is, the more oxygen it needs to live.

26. Although some people think that earthworms are only brown, they come in many different colours including brown, green, and purple.

27. Earthworms need to be in the soil to breathe.

28. Many animals and birds eat rattlesnakes.

29. Worker bees dance to tell other bees where there is food.

30. There are more animals without backbones than animals with backbones, although some people think that there are more animals with backbones.

31. Bees often dig small holes in the ground, although some people do not think that bees dig holes.

32. Although some people think that rattlesnakes have smooth heads, most rattlesnakes have small scales on their heads.
Study Order: 2

Practice Sentences:
1. The blue whale only eats for about three months of the year.
2. The swift fox sleeps all day, although some people think that the fox is awake during the day.
3. Baby deer do not need to hide in the forest when they become adults.
4. Although some people think that a spider is an insect, a spider is not an insect.

To-Be-Learned Sentences:
1. Moon soil is made up of small pieces of rock and glass.
2. In space, the sun's heat cannot even roast a potato.
3. Although some people think that the size of a star is always the same, the size changes.
4. Oxygen is not the same as air.
5. The distance between the earth and the moon changes everyday, although some people think that it is always the same.
6. Although some people think that the light of the sun is only red and yellow, it is made of every different colour including blue and violet.
7. Stars are gases, although some people think that they are solid.
8. The largest known volcano is on the planet Mars.
9. New plants can grow from roots, stems, and leaves.
10. Although some people think that plants always need light, plants do not always need light.
11. Maple keys and milkweed pods are fruits, although some people do not think that they are.
12. Plants do not get food from the soil.
13. Not all plants have roots, although some people think that all plants have them.
14. Although some people do not think that all human food comes from green plants, all human food originally comes from plants.
15. The most important reason why plants need water is to cool off their leaves.
16. The soil provides plants with oxygen.
17. There are more animals without backbones than animals with backbones.
18. Although some people think that all animals need the same amount of oxygen to live, the larger an animal is, the more oxygen it needs.
19. Worker bees dance to tell each other where there is food, although some people think that they buzz.
20. Most rattlesnakes have small scales on their heads.
21. Although some people do not think that lots of animals and birds eat rattlesnakes, many animals and birds eat them.
22. Earthworms need to be in the soil to breathe, although some people think that they can breathe anywhere.
23. Earthworms come in many different colours including brown, green, and purple.
24. Bees often dig small holes in the ground.
25. The heart pumps both blood with oxygen and blood without oxygen.
26. There are four main types of blood.
27. Pus is white blood cells that have died.
28. Some living things have only one cell.
29. Although some people think that blood cells last for a lifetime, new red blood cells are needed about every four months.
30. Although some people think that the heart makes and stores blood, its only function is to pump blood.
31. Respiration is not the same as breathing, although some people think that they are the same.
32. Only the left side of the heart pumps blood to the body, although some people think that both sides pump blood to the body.
Appendix E

Posttest Questionnaires:

Experiment 1
Appendix E

1. In space, the sun's heat cannot even roast a potato.
2. In space, the sun's heat can easily roast a potato.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. Many animals and birds do not eat rattlesnakes.
2. Many animals and birds eat rattlesnakes.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. There are four main types of blood.
2. There is only one main type of blood.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. Plants do not always need light.
2. Plants always need light.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. Earthworms need to be in the soil to breathe.
2. Earthworms do not need to be in the soil to breathe.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. New plants can only grow from seeds.
2. New plants can grow from roots, stems, and leaves.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. The largest known volcano is on the planet Mars.
2. The largest known volcano is on the planet Earth.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE
1. Oxygen is the same as air.
2. Oxygen is not the same as air.

The correct sentence is number _____

I am 100% SURE, 50% SURE, 100% UNSURE

1. Some living things have only one cell.
2. All living things have more than one cell.

The correct sentence is number _____

I am 100% SURE, 50% SURE, 100% UNSURE

1. Stars are solid.
2. Stars are gases.

The correct sentence is number _____

I am 100% SURE, 50% SURE, 100% UNSURE

1. Earthworms come in many different colours including brown, green, and purple.
2. Earthworms do not come in many different colours, only brown.

The correct sentence is number _____

I am 100% SURE, 50% SURE, 100% UNSURE

1. Maple keys and milkweed pods are fruits.
2. Maple keys and milkweed pods are not fruits.

The correct sentence is number _____

I am 100% SURE, 50% SURE, 100% UNSURE

1. Pus is not white blood cells.
2. Pus is white blood cells that have died.

The correct sentence is number _____

I am 100% SURE, 50% SURE, 100% UNSURE

1. Plants get their food from the soil.
2. Plants do not get their food from the soil.

The correct sentence is number _____

I am 100% SURE, 50% SURE, 100% UNSURE
1. Worker bees dance to tell other bees where there is food.
2. Worker bees buzz to tell other bees where there is food.

The correct sentence is number ________

I am 100% SURE, 50% SURE, 100% UNSURE

1. The light of the sun is made of every different colour including red, yellow, blue, and violet.
2. The light of the sun is made of only a few colours, mostly red and yellow.

The correct sentence is number ________

I am 100% SURE, 50% SURE, 100% UNSURE

1. All animals need the same amount of oxygen.
2. The larger an animal is, the more oxygen it needs.

The correct sentence is number ________

I am 100% SURE, 50% SURE, 100% UNSURE

1. Moon soil is only made up of small pieces of rock.
2. Moon soil is made up of small pieces of rock and glass.

The correct sentence is number ________

I am 100% SURE, 50% SURE, 100% UNSURE

1. The only function of the heart is to pump blood.
2. The functions of the heart include making, storing, and pumping blood.

The correct sentence is number ________

I am 100% SURE, 50% SURE, 100% UNSURE

1. The heart only pumps blood with oxygen.
2. The heart pumps both blood with oxygen and blood without oxygen.

The correct sentence is number ________

I am 100% SURE, 50% SURE, 100% UNSURE
1. All human food does not come from green plants.
2. All human food comes from green plants.

The correct sentence is number _____

I am 100% SURE,  50% SURE,  100% UNSURE

1. There are more animals with backbones than without backbones.
2. There are more animals without backbones than animals with backbones.

The correct sentence is number _____

I am 100% SURE,  50% SURE,  100% UNSURE

1. The distance between the earth and the moon changes everyday.
2. The distances between the earth and the moon stays the same.

The correct sentence is number _____

I am 100% SURE,  50% SURE,  100% UNSURE

1. The most important reason why plants need water is to cool off their leaves.
2. The most important reason why plants need water is to drink.

The correct sentence is number _____

I am 100% SURE,  50% SURE,  100% UNSURE

1. Both sides of the heart pump blood to the body.
2. Only the left side of the heart pumps blood to the body.

The correct sentence is number _____

I am 100% SURE,  50% SURE,  100% UNSURE

1. Not all plants have roots.
2. All plants have roots.

The correct sentence is number _____

I am 100% SURE,  50% SURE,  100% UNSURE
1. Rattlesnakes have smooth heads.
2. Rattlesnakes have small scales on their heads.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. The soil does not provide plants with oxygen.
2. The soil provides plants with oxygen.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. The size of a star stays the same.
2. The size of a star changes.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. New red blood cells are needed about every four months.
2. New red blood cells are needed only once in a lifetime.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. Respiration is the same as breathing.
2. Respiration is not the same as breathing.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. Bees dig small holes in the ground.
2. Bees do not dig small holes in the ground.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE
Appendix F

Practice Sentences and To-Be-Learned Sentences:

Experiment 2
Appendix F

Study Order: 1

Practice Sentences:

1. Rocks store heat.
2. There is water in rocks.
3. Rocks break or decay very slowly in the desert.
4. There is air in rocks.

To-Be-Learned Sentences:

1. Some living things have only one cell.
2. Respiration is not the same as breathing.
3. There are four main types of blood.
4. The only function of the heart is to pump blood.
5. New red blood cells are needed about every four months.
6. The heart pumps both blood with oxygen and blood without oxygen.
7. Pus is white blood cells that have died.
8. Only the left side of the heart pumps blood to the body.

9. All human food comes from green plants.
10. Not all plants have roots.
11. Not all new plants come from seeds.
12. Maple keys and milkweed pods are fruits.
13. Plants do not get their food from the soil.
15. The soil provides plants with oxygen.
16. In plants, food travels from the leaves to the roots.

17. Oxygen is not the same as air.
18. Moon soil is made up of small pieces of rock and glass.
19. In space, the sun's heat cannot even roast a potato.
20. The distance between the earth and the moon changes everyday.
21. The light of the sun is made of every different colour including red, yellow, blue, and violet.
22. The size of a star changes.
23. The largest volcano is on the planet Mars.
24. Much of the sun's solar energy never reaches the Earth.
25. The larger the animal is, the more oxygen it needs to live.
26. Earthworms come in many different colours including brown, green, and purple.
27. Worker bees dance to tell other bees where there is food.
28. Earthworms will die from a lack of oxygen if they are not in the soil.
29. Bees often dig small holes in the ground.
30. Many animals and birds eat rattlesnakes.
31. There are more animals without backbones than animals with backbones.
32. Rattlesnakes have small scales on their heads.

**Study Order 2:**

**Practice Sentences:**

1. Rocks store heat.
2. There is air in rocks.
3. Rocks break or decay very slowly in the desert.
4. There is water in rocks.

**To-Be-Learned Sentences:**

1. Worker bees dance to tell other bees where there is food.
2. The larger an animal is, the more oxygen it needs to live.
3. There are more animals without backbones than animals with backbones.
4. Rattlesnakes have small scales on their heads.
5. Earthworms come in many different colours including brown, green, and purple.
6. Many animals and birds eat rattlesnakes.
7. Bees often dig small holes in the ground.
8. Earthworms will die from a lack of oxygen if they are not in the soil.
9. Only the left side of the heart pumps blood to the body.
10. Pus is white blood cells that have died.
11. Respiration is not the same as breathing.
12. Some living things have only one cell.
13. The only function of the heart is to pump blood.
14. New red blood cells are needed about every four months.
15. The heart pumps both blood with oxygen and blood without oxygen.
16. There are four main types of blood.
17. Maple keys and milkweed pods are fruits.
18. Not all plants have roots.
19. Not all new plants come from seeds.
20. The soil provides plants with oxygen.
21. Plants do not get their food from the soil.
22. In plants, food travels from the leaves to the roots.
23. Rock decay helps make soil needed for plant growth.
24. All human food comes from green plants.

25. Much of the sun's solar energy never reaches the Earth.
26. The size of a star changes.
27. The light of the sun is made of every different colour including red, yellow, blue, and violet.
28. Oxygen is not the same as air.
29. The distance between the earth and the moon changes everyday.
30. Moon soil is made up of small pieces of rock and glass.
31. In space, the sun's heat cannot even roast a potato.
32. The largest volcano is on the planet Mars.
Appendix G
Posttest Questionnaires:
Experiment 2
Appendix G

1. In space, the sun's heat cannot even roast a potato.
2. In space, the sun's heat can easily roast a potato.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. Many animals and birds do not eat rattlesnakes.
2. Many animals and birds eat rattlesnakes.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. There are four main types of blood.
2. There is only one main type of blood.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. In plants, food travels from the leaves to the roots.
2. In plants, food travels from the roots to the leaves.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. Earthworms need to be in the soil to breathe.
2. Earthworms do not need to be in the soil to breathe.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. All new plants come from seeds.
2. Not all new plants come from seeds.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. The largest known volcano is on the planet Mars.
2. The largest known volcano is on the planet Earth.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE
1. Oxygen is the same as air.
2. Oxygen is not the same as air.

The correct sentence is number ______
I am 100% SURE, 50% SURE, 100% UNSURE

1. Some living things have only one cell.
2. All living things have more than one cell.

The correct sentence is number ______
I am 100% SURE, 50% SURE, 100% UNSURE

1. Almost all of the sun's solar energy reaches the Earth.
2. Much of the sun's solar energy never reaches the Earth.

The correct sentence is number ______
I am 100% SURE, 50% SURE, 100% UNSURE

1. Earthworms come in many different colours including brown, green, and purple.
2. Earthworms do not come in many different colours, only brown.

The correct sentence is number ______
I am 100% SURE, 50% SURE, 100% UNSURE

1. Maple keys and milkweed pods are fruits.
2. Maple keys and milkweed pods are not fruits.

The correct sentence is number ______
I am 100% SURE, 50% SURE, 100% UNSURE

1. Pus is not white blood cells.
2. Pus is white blood cells that have died.

The correct sentence is number ______
I am 100% SURE, 50% SURE, 100% UNSURE

1. Plants get their food from the soil.
2. Plants do not get their food from the soil.

The correct sentence is number ______
I am 100% SURE, 50% SURE, 100% UNSURE
1. Worker bees dance to tell other bees where there is food.
2. Worker bees buzz to tell other bees where there is food.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. The light of the sun is made of every different colour including red, yellow, blue, and violet.
2. The light of the sun is made of only a few colours, mostly red and yellow.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. All animals need the same amount of oxygen.
2. The larger an animal is, the more oxygen it needs.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. Moon soil is only made up of small pieces of rock.
2. Moon soil is made up of small pieces of rock and glass.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. The only function of the heart is to pump blood.
2. The functions of the heart include making, storing, and pumping blood.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. The heart only pumps blood with oxygen.
2. The heart pumps both blood with oxygen and blood without oxygen.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE
1. All human food does not come from green plants.
2. All human food comes from green plants.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. There are more animals with backbones than without backbones.
2. There are more animals without backbones than animals with backbones.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. The distance between the earth and the moon changes everyday.
2. The distances between the earth and the moon stays the same.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. The decay of rocks helps make soil needed for plant growth.
2. The decay of rocks does not help make soil needed for plant growth.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. Both sides of the heart pump blood to the body.
2. Only the left side of the heart pumps blood to the body.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. Not all plants have roots.
2. All plants have roots.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE
1. Rattlesnakes have smooth heads.
2. Rattlesnakes have small scales on their heads.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. The soil does not provide plants with oxygen.
2. The soil provides plants with oxygen.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. The size of a star stays the same.
2. The size of a star changes.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. New red blood cells are needed about every four months.
2. New red blood cells are needed only once in a lifetime.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. Respiration is the same as breathing.
2. Respiration is not the same as breathing.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE

1. Bees dig small holes in the ground.
2. Bees do not dig small holes in the ground.

The correct sentence is number ______

I am 100% SURE, 50% SURE, 100% UNSURE
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