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ABSTRACT

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Using Elaborative Interrogation To Help Students Overcome Their Inaccurate Science Beliefs

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Abstract

One hundred and forty students in grades 6 and 7 were asked to process 32 science statements. Half of the statements were consistent with their prior knowledge, whereas the remaining facts were inconsistent with it. Half of the students were instructed to read the sentences for understanding (reading controls). 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) followed. Experiment 2 subjects also completed 75-day and 180-day recognition tasks. Across all memory measures, elaborative-interrogation subjects performed significantly better than did reading-controls. The quality of the elaborative-interrogation study responses did not affect retention. All students recognized more belief-consistent facts than belief-inconsistent facts. Elaborative-interrogation subjects were less confident in their incorrect recognition selections than were reading controls who expressed great confidence in their erroneous answers.

Using Elaborative Interrogation To Help Students Overcome Their Inaccurate Science Beliefs

Learning is often facilitated when students relate to-be-learned information to content that they already know. Specifically, when learners possess prior knowledge that is consistent with target information, learning of new information can be facilitated (e.g., Brown, Smiley, Day, Townshead, & Lawton, 1977; Pearson, Hanson, & Gordon, 1977). Sometimes students possess prior knowledge that directly contradicts content they are expected to learn (otherwise known as alternative frameworks, naive conceptions, or misconceptions). The impact of such contradictory knowledge on student learning has been of particular interest to science educators (e.g., Alvermann, Smith, & Readence, 1985; Roth, 1990, 1991; Roth, Anderson, & Smith, 1987). If students simply read information that is inconsistent with their prior knowledge, inaccurate beliefs usually are greater determinants of long-term understanding than is new information (for a review, see Guzzetti, Snyder, & Glass, 1992). For example, many students allow inaccurate beliefs to override scientific information about photosynthesis (e.g., they continue to believe that plants eat soil following instruction about photosynthesis; Roth, 1990, 1991). Even if the new information is retained for short-term recall, long-term retention often reflects the inaccurate belief.

Inaccurate science beliefs are pervasive, resistant to change, and impede acquisition of new content (e.g., Champagne, Klopfer, & Gunstone, 1982; Roth, Anderson, & Smith, 1987). Instructional methods that increase student awareness of inconsistencies between new content and prior knowledge need to be developed, for acknowledging inconsistencies between prior knowledge and new information is a critical first step in overcoming inaccurate beliefs (e.g., Nussbaum & Novick, 1982). Refutational text is one method designed to promote awareness of such inconsistencies. Refutational statements both support new information and discredit inaccurate beliefs. For example, the statement, "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" highlights that the light of the sun is made up of every different colour despite its reddish-orange appearance.

Reading refutational text helps many students overcome their inaccurate beliefs (e.g., Alvermann & Hague, 1989; Hynd, & Alvermann, 1986, 1987). Moderate effect sizes (i.e., 0.4 to 0.9 SDs; Cohen, 1977) have been associated with the use of refutational text relative to traditional text as measured by memory, comprehension, and application tests (Guzzetti et al., 1992). The present study investigated whether acquisition of information that was inconsistent with students' existing beliefs could be enhanced further by using elaborative interrogation, a question-answering strategy.

Students probably possess both knowledge that is consistent, and knowledge that is inconsistent, with new information. Thus, for the fact, "The light of the sun is made up of every different colour", a student might have some prior knowledge supporting that position (e.g., he or she has seen a prism, he or she realizes the perceived colour of an object represents a reflection of some of the sunlight), and some seemingly inconsistent information (e.g., the sun appears orange and red). When inconsistent knowledge is more familiar and salient than consistent knowledge, as in this example, it is also more likely to affect thinking and new learning. In other words, the inaccurate belief will be recalled and applied more readily than will the new information or any prior knowledge consistent with it. Alternatively, if learners reflected on the new information so that it was associated with supportive prior knowledge, and/or the validity of the inaccurate belief was discredited, then learning of the new content might be enhanced. Elaborative interrogation (i.e., answering why questions about to-be-learned materials) promotes this type of processing.

Learners must think deeply about new information and relate it to supportive prior knowledge if they are to generate credible responses to why-questions (i.e., Why is this fact true)? Pressley and his colleagues have amassed substantial evidence that generating answers to why questions enhances learning of facts that are consistent with prior knowledge for both adults and children in the later elementary-school years (e.g., Pressley, Symons, McDaniel, Snyder, & Turnure, 1988; Pressley, Wood, Woloshyn, Martin, King, & Menke, 1992; Woloshyn, Pressley, & Schneider 1992; Wood, Pressley, & Winne, 1990). In fact, elaborative-interrogation learning gains are as large as those produced by imagery, a strategy well known to facilitate learning (e.g., Paivio, 1971; Paivio & Yuille, 1967). However, the facts learned in previous studies of elaborative interrogation were ones that did not clash with salient prior knowledge. In contrast, in this study, elaborative interrogation was evaluated with respect to information inconsistent with learners' existing beliefs. Although we were hopeful that students would be able to relate to-be-learned content to supportive (albeit, less salient) prior knowledge, we feared that students' inaccurate beliefs would interfere with the construction of supportive elaborative explanations. Even if students could relate the new content to prior knowledge consistent with to-be-learned facts, there was no guarantee that elaborative-interrogation effects would override the effects of long-held misbeliefs on learning. Whether elaborative interrogation could facilitate acquisition of content directly contradictory to previous beliefs seemed to be a challenging test of the general hypothesis that elaborative interrogation improves learning of factual content.

A pilot study was carried out to obtain scientific facts that were inconsistent with students' existing beliefs. Some of these facts were used in the first experiment where middle-school students were asked to learn facts pertaining to four scientific topics. The facts were presented either in traditional text, refutational text (refutation of inaccurate belief plus scientific information), or inverted refutational text (scientific information plus refutation of inaccurate belief). Half of the to-be-learned facts were inconsistent with students' prior knowledge, whereas the remaining facts were consistent with their existing beliefs. The participants were either instructed to generate answers to why-questions for each fact (elaborative interrogation), or to read the statements for understanding (reading control). Four measures of learning were taken, two involving recall of facts and two involving a recognition task requiring students to discriminate each fact from its inaccurate counterpart.

Pilot Study

Selection of Potential Study Items

One hundred and eighty sentences were selected from science texts and published research. Each statement pertained to a concept about which students often possess inaccurate beliefs. The statements covered a variety of topics including the solar system, three states of matter, plants, animals, and AIDS (e.g., Not all plants have roots, There is empty space between molecules, It is not easy to detect a person with AIDS). For each true sentence, a false statement was created by either negating it or by substituting a popular falsehood (eg., All plants have roots, There is air between molecules, It is easy to detect a person with AIDS).

These statements were used to develop twelve, 15-item questionnaires. The questionnaires were similar in format to those used by Lipson (1982), with an individual test item consisting of two sentence pairs: one sentence representing a scientific fact, the other representing an inaccurate belief about the scientific fact (e.g., The sun is not alive, The sun is alive). The phrase, "The correct sentence is number ___" and the words, "100% SURE", "50% SURE", and "100% UNSURE" appeared below each pair.

Ninety-six students (60 in grades 7 and 8, and 36 in grades 5 and 6), were recruited from local boys and girls organizations. All students were proficient English speakers. The students were instructed to read each sentence pair, select the statement that they believed was true, and indicate their response certainty. It was explained that they should circle 100% SURE when they were very confident that their answers were correct, 50% SURE when they were fairly certain that their selection was correct but had some concerns about accuracy, and 100% UNSURE when they were guessing.

Ninety items were selected for further study on the basis of these students' responses. Facts that were generally well known and facts about which students had no relevant knowledge were discarded. Four, 35-item questionnaires, identical in format to those used previously, were constructed from the remaining items.

Selection of Experimental Materials

One hundred and sixty students (40 in each of grades 5, 6, 7, and 8), completed the revised questionnaires. The students attended one of two elementary schools and were proficient English speakers. The students were seen as a group, and told that their help was being solicited by researchers who wanted to know what information was familiar to children in their grade. Ten students in each grade were randomly assigned to complete one of the four questionnaires. Instructions were identical to those described earlier.

Sixteen science statements were selected for experimental use on the basis of these students' responses (4 statements for each of 4 content areas: solar system, circulatory system, plants, and animals). Specifically, a scientific statement was chosen if at least 50% of the children in each grade selected its false counterpart as "correct" with either 100% or 50% certainty. An additional 16 facts were constructed from published research and unused portions of science texts (4 facts for each content area). These facts were selected on the basis that they were consistent with most children's existing beliefs and presented students with new information (teachers confirmed that the facts were consistent with most students' existing beliefs and that they had not been previously studied). These facts could also be negated for use in the refutational text conditions. In total, 32 statements (16 consistent with students' existing beliefs, and 16 inconsistent with those beliefs) were constructed for use in the Experiment 1 (see Appendix A for a listing of experimental materials according to prior knowledge consistency and text type).

Experiment 1

Subjects

The participants were the same 60 6th-grade (16 males and 14 females, M = 11.4 years old, SD = .56) and 7th-grade (17 males and 13 females, M = 12.40 years old, SD = .56) students who completed the pretest questionnaires used to develop materials for Experiment 1. Fifteen students from each grade were randomly assigned to either the elaborative interrogation or reading control conditions. All subjects were seen individually. There was a 21-day interval between pilot testing and the first experimental session.

Materials

Two sets of the to-be-learned materials were constructed. Each set contained 36 cue cards, with one factual statement printed per card. The facts were written in one of three formats: traditional, refutational, or inverted refutational. Statements written in traditional format contained only the science fact (i.e., Oxygen and air are not the same). All other statements contained both the science fact and a refutation of a common misbelief. For refutational format, the inaccurate belief was presented first, followed by the science fact (e.g., Although some people think that oxygen and air are the same, they are not the same). This order was reversed for inverted refutational format (e.g., Oxygen and air are not the same, although some people think that they are the same).

The order of sentence presentation also differed across the two sets of materials. Students were assigned randomly to one of the two orders. An audio recording of the study materials was also made by an adult male. The tape was used to ensure that all subjects processed the facts at least once.

One practice set consisting of 4 animal facts was presented at the beginning of the study session (2 inconsistent with students' existing beliefs, 2 consistent with their beliefs). For the 32 critical statements, 16 (8 inconsistent with students' existing beliefs, 8 consistent with their beliefs) were written in traditional format. The remaining statements were written in refutational format and inverted refutational format (4 inconsistent with students' beliefs, 4 consistent with these beliefs for each text type). Statements that appeared in traditional format in the first study order were presented in one of the two refutational forms in the second order and vice versa.

An orienting instruction was typed on a stand-up cue card. The prompt for the reading-control condition was, "Read the sentence out loud at a rate that allows you to understand that the fact is true." The prompt for the elaborative-interrogation condition was, "Why is that fact true?" Students' responses were audio recorded for subsequent analyses.

Procedure

Instructions

The students were told that they would see individual sentences stating true facts about four science topics, and that they would be asked about these facts later. They were provided examples of the three text types and informed that the nature of their task would remain constant regardless of text format. The specific instructions given to students varied as a function of experimental condition.

Elaborative-interrogation subjects were instructed to read each statement silently, but to answer aloud the associated "why" question. These students were instructed to use information that they had acquired in their classes, readings, and everyday experiences to help them answer the why questions. They were provided with the following instructions:

> I am going to show you true statements about 4 different topics. Even though the facts may seem surprising, they are 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?" In order to help you generate an answer, you might want to think about information that your teachers have told you in class, information that you have read about in books, and your everyday experiences. It is very important that you attempt to answer each question. Even if you are not sure that your answer is correct, make your best guess. 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 think of an answer for every question. Do not be upset about this. Just try your best to answer each question. When you hear the sound of the bell you must go on to the next sentence, even if you have not completed your answer. Try to answer every question as I am going to ask you about the sentences later.

Reading-control subjects were asked to read each statement aloud in a continuous manner for the entire time that the statement was presented. It was stressed that the facts should be read for meaning.

> I am going to show you true statements about 4 different topics. Even though the facts may seem surprising, they are true. Your task is to read each sentence out loud at a rate that permits 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 bell and a new sentence is presented. It is very important that you read each sentence out loud at a rate that permits 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 sentences later.

Four practice sentences were presented at the beginning of the session, with students demonstrating how they would carry out their assigned strategy. Subjects received feedback about their performance as well as an example of an appropriate response. The 32 critical statements were then presented for 20 seconds intervals.

Retention Measures and Posttest Interview

Retention for study materials was assessed via two tests of recall (free and cued) and two tests of recognition (immediate and 14-day delayed). For free recall, students were instructed to remember as many of the facts as possible given only the four topic titles. Topics were presented in a random order, except that the last topic studied was never the first tested. Participants were informed that one way to enhance recall was to reflect on how information was processed (i.e., consistent with principles of encoding specificity theory; Tulving & Thomson, 1973). Specifically, elaborative-interrogation subjects were told that trying to remember their answers to the why questions might help them remember the study statements. Reading-controls were told that reflecting on how information was read might help them recall more facts.

Students signalled when they were unable to recall any more facts and the experimenter provided them with cued recall prompts. Each prompt contained two critical pieces of sentence information (e.g., Tell me about the colour of the sun, Tell me about oxygen and air). Prompts were presented in a random order, with this process repeated until all study topics were reviewed.

A posttest interview was administered after the recall tests. The interview assessed adherence to processing instructions and students perceptions of task difficulty. All students were shown three study statements (one written in each text format) and asked to elaborate on what they were thinking when they read the sentences for the first time. In addition, on a scale from one (very easy) to ten (very hard), participants rated (a) how difficult they found their assigned task and (b) the readability of the three texts.

The experimental session ended with students completing a recognition test which took the same form as the questionnaire used for piloting (i.e., select the science fact from opposing sentence pairs, and circle response certainty for each item). This measure was completed for a second time approximately 14 days after the experimental session. The following instructions were used to direct students:

I am going to ask you to complete a science questionnaire. The questionnaire is very similar to the one you completed a few weeks ago. Do you remember that questionnaire? When completing the questionnaire, you will need to read each sentence pair and decide whether you believe sentence number one, or sentence number two, is correct. It is important to think about the information that you have read when completing the questionnaire. For each item, you also have to circle whether you are 100% Sure, 50% Sure, or 100% Unsure about your response. Remember that 100% Sure means that you are very certain about your response, 50% Sure means that you are fairly certain but have some doubts, and 100% Unsure means that you are guessing.

Results

The primary analyses involved the recall and recognition data. A maximum score of 32 could be received for each of these tests (16 points for facts addressing common misbeliefs; 16 points for facts that were consistent with students' prior knowledge). Secondary analyses involved subjects' certainty ratings for their recognition responses (ideally, elaborative interrogation would not only facilitate successful recognition, but also enhance students' confidence for correct selections). The relationship between the quality of students' answers to the elaborative-interrogation "why" questions and subsequent learning was also investigated. All posttest interviews were analyzed.

Two independent raters analyzed the free and cued recall responses. A response was considered correct if it was synonymous with the fact presented at study. 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.

Subjects raw scores were converted into proportions correct (to allow for meaningful comparisons across the three text types). The mean proportions and standard deviations are listed in Table 1. For each of the four memory measures, a 2 (strategy)

Insert Table 1 about here

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by 2 (fact) by 3 (text) ANOVA was carried out, with repeated measurement on the last two variables. Tukey's HSD approach was used for post hoc analyses ($p \leq .05$).

Learning Gains Due to Strategy

Across all the recall and recognition measures, there were significant main effects for strategy [$F(1,58) \geq 14.02$, $p<.001$]. Instructions to use elaborative interrogation produced better learning performances than did instructions to read for understanding ($q \geq 3.38$, $p<.01$).

Subjects' free and cued recall responses were analyzed for extraneous statements and statements that were inconsistent with to-be-learned facts (elaborative-interrogation learning gains might be artifacts of more recall attempts). There were no significant differences in the number of erroneous statements generated by students as a function of experimental condition [extraneous statement $F(1,58) \leq 1.65$; incorrect statement $F(1,58) \leq .59$].

Learning Gains Due to Fact Type

There were no significant differences associated with fact type for either free or cued recall tests [$F(1,58) \leq .53$, $p > .05$]. However, for both immediate and 14-day recognition tests, there was a main effect for fact type [$F(1,58) \geq 16.40$, $p < .001$]. Subjects recognized more facts that were consistent with prior knowledge than facts that were inconsistent with their existing beliefs ($q \leq 3.16$).

Learning Gains Due to Text Type

For both free and cued recall tests, there were significant main effects for text type [$F(2,116) \geq 7.78$, $p < .001$]. For free recall, the text by fact interaction was also significant [$F(2,116) = 3.10$, $p < .05$].[1] Reading refutational text enhanced free recall for facts relative to reading traditional text ($q = 3.78$, $p < .01$), and enhanced both free and cued recall relative to reading inverted refutational text ($q \geq 3.79$, $p < .01$). There were no recall differences between inverted refutational text and traditional text ($q \leq 1.40$). Cued recall performances did not differ significantly between inverted refutational text and refutational text ($q \leq 2.39$).

For immediate recognition, the main effect for text type was not significant [$F(2,116) = 2.80$], although there was a significant interaction between fact type and text type [$F(2,116) = 3.71$, $p < .05$].[2] There was also a significant interaction between strategy and text type [$F(2,116) = 3.25$, $p < .05$].[3]

For 14-day recognition, there was a significant main effect for text type [$F(2,116) = 5.69$, $p < .005$]. Reading refutational text enhanced retention relative to reading inverted refutational text ($q = 3.06$, $p<.05$) for both facts that were consistent and facts that were inconsistent with students prior beliefs. There were no significant interactions.

Certainty Responses for Recognition Tests

Instructions to use elaborative interrogation affected confidence for both correct recognition selections and erroneous ones. These certainty responses are presented in Table 2 as a function of experimental condition. For each recognition

Insert Table 2 about here

measure and fact type, a 2 (strategy) by 2 (accuracy) by 3 (certainty) ANOVA with repeated measurement on the last two variables was carried out.

For both facts that addressed common misbeliefs and facts that were consistent with students' existing beliefs, there were significant three way interactions [immediate $F(2,116) \geq 8.74$, $p<.001$; 14-day $F(2,116) \geq 8.05$, $p<.001$]. For facts that were inconsistent with learners' prior beliefs, elaborative-interrogation subjects recognized more study statements with 100% certainty than did reading-control subjects (smaller $q = 8.05$, $p<.01$). Reading-controls endorsed more incorrect statements with great certainty than did elaborative-interrogation subjects (i.e., 50% certainty for immediate recognition, $q = 9.03$; 100% certainty for 14-day recognition, $q = 3.58$).

For facts that were consistent with learners' prior beliefs, elaborative-interrogation subjects recognized 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-day test ($q = 3.58$, $p<.05$), although reading-controls recognized more facts with 50% certainty on the immediate test (probably an artifact of elaborative-interrogation students' recall of facts with maximum certainty, $q = 4.40$, $p<.01$). There were no other significant differences between the two conditions for either correct or incorrect selections (larger $q \leq 2.98$).

Relationship Between Elaborative-Interrogation Study Responses and Subsequent Learning

Two independent raters scored the elaborative-interrogation study responses using criteria similar to those used by Pressley et al. (1988) and Woloshyn et al. (1990). Specifically, answers were scored as "adequate", "inadequate", or "no response". Adequate responses were those that made clearer why the given facts were true. For example, one adequate response for the statement, "Oxygen is not the same as air" is, "Air is made of many different elements including oxygen". For the statement "Some living things have only one cell", an adequate response is, "Some animals are so small they only need one cell". All other responses were classified as inadequate. For example, the statements, "Because of the chemicals" and, "They are made that way" were scored as inadequate. Failures to respond were classified as no response. Raters agreed on 89% of the response classifications, with all 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 3. There was only

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Insert Table 3 about here

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one significant difference: For the immediate recognition test, items associated with adequate responses were retained better than were items associated with response failures ($q = 3.87$, $p < .05$).

Posttest Interview

Subjects in both the elaborative-interrogation and reading-control conditions reported using their assigned study strategy more than any other method of study (57.74% and 35.71% of the probes respectively). Use of alternative approaches was infrequent (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). Reading-control subjects reported surprise and/or disbelief about the study information almost twice as often as elaborative-interrogation subjects (35.71% versus 19.54% of the probes).

In order to assess task and text difficulty, a 2 (strategy) by 4 (passage) ANOVA was carried out with repeated measurement on passage. The main effect for strategy was not significant [$F(1,58) = 3.15$], although elaborative-interrogation subjects rated their task more difficult than did reading-controls (overall elaborative-interrogation M = 5.11, overall reading-control M = 4.32). The main effect for text was significant [$F(2,116) = 3.87$, $p < .02$]. Students rated traditional text easier to comprehend than either refutational format ($q \geq 3.04$, $p < .05$). There was no other significant difference.

Summary

There were four main findings. (1) Instructing students to use elaborative interrogation facilitated learning for both facts that were consistent with prior knowledge and facts that were inconsistent with this information relative to instructing students to read for understanding. (2) The quality of students' elaborative-interrogation study responses had little affect on retention. Even when subjects failed to generate an answer to the why question, or generated an answer that contained irrelevant information, learning was facilitated relative to reading. (3) All students had more difficulty recognizing facts that were inconsistent with their prior beliefs than ones that were consistent with these beliefs. (4) Reading refutational text provided better retention than did reading traditional text or inverted refutational text.

Discussion

Instructing students to answer "why" questions enhanced learning on both recall and recognition tasks relative to instructing students to read for understanding. Learning was facilitated regardless of whether students studied facts that were consistent with their prior beliefs or facts that were inconsistent with these beliefs. This is an impressive finding as students often allow their inaccurate beliefs, which are usually more familiar and salient than prior knowledge consistent with to-be-learned content, to override text information (e.g., Alvermann et al., 1985; Lipson, 1982). Even when elaborative-interrogation subjects made incorrect recognition responses, they were less certain about their selections than were reading-controls, who often expressed great confidence in their erroneous decisions. In short, there were a number of indications of greater learning in the elaborative-interrogation condition than in the reading-control one, extending the general conclusion that elaborative interrogation facilitates learning of facts (Pressley, et al., 1992).

Martin and Pressley (1992) demonstrated that answering questions that diverted attention from the presented facts by requiring students to use information that contradicted them did not improve learning. Only questions that required learners to seek confirming or supportive prior knowledge improved learning relative to the reading-control condition. The elaborative-interrogation instructions used in this experiment required learners to search for knowledge that supported the to-be-learned content so that they could elaborate and make inferences about the critical facts. Presumably, this process of searching for supportive information accentuated inconsistencies between new content and prior beliefs, encouraging students to discredit their inaccurate beliefs and adopt scientific ones.

Our initial concern that answering why questions would not be sufficient to discredit long-held inaccurate beliefs was not warranted. Even when subjects were unable to provide responses that made clearer why the presented facts were true (i.e., adequate responses), their active attempts to do so enhanced learning relative to reading for understanding, probably because attempting to generate an adequate response activated a network of information related to the critical fact (see Slamecka & Fevrieski, 1983).

All subjects recognized, but did not recall, more facts that were consistent with their prior knowledge than facts that were inconsistent with this knowledge. The recall versus recognition discrepancy can probably be attributed to differences between the tasks. For the recall tasks, students were required to access critical information in memory and decide whether it was presented at study. If learners activated conflicting responses, they had the option of not responding. For the recognition tasks, students were presented with competing items and were required to select a response, increasing the likelihood of a decision error.

There was some advantage for reading refutation text relative to reading either traditional or inverted refutation text. Retention advantages were likely due to the presentation of both scientifically accepted facts and refutations of inaccurate beliefs. Because common misbeliefs were refuted in an impersonal and nonthreatening manner (i.e., text was written to draw attention to what some people wrongly believe and not necessarily to the students' incorrect beliefs), learners may have been encouraged to make comparisons between their existing beliefs and scientifically accepted thought rather than to defend their thinking. Anecdotal comments made by some students, especially reading controls, suggested that refutation text promoted this type of reflection.

Experiment 2

Experiment 2 sought to replicate the finding that elaborative-interrogation instructions facilitate science learning relative to instructions to read for understanding. The study also investigated the effects of explicitly activating prior knowledge before study.

Eighty students in grades 6 and 7 participated in this study. Students were given either elaborative-interrogation or reading-control instructions. Half the students in each condition were instructed to activate relevant knowledge about the to-be-learned science topics prior to study (activators). The remaining students were instructed to activate knowledge about unrelated topics (nonactivators). The same memory measures used in Experiment 1 were also used in this study. In addition, students completed 75-day and 180-day recognition tests.

On the basis of previous findings, reading controls who activated prior knowledge that was inconsistent with text were expected to allow their inaccurate beliefs to override text information and perform poorly on memory measures relative to reading-control subjects who activated prior knowledge about unrelated content. However, activators should demonstrate superior retention for 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 facts. When learners activate knowledge that can be used as part of a supportive elaborative-interrogation response (i.e., information that is consistent with text), learning may be improved relative to activating irrelevant information. Specifically, the time needed to search memory for an answer to the why question might be reduced, allowing learners more time to establish a meaningful association. On the other hand, activation of information that cannot be included in a supportive elaborative-interrogation response (i.e., information that is inconsistent with text) might either have no effect 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 information). In the later case, elaborative-interrogation students who are instructed to activate information about unrelated content would retain more study information than students who are instructed to activate information about to-be-learned content.

Method

Pretest Questionnaire

Prior to participating in the experimental session, 60 students in grade 6 and 72 students in grade 7 completed a 90-item science questionnaire similar in format to the one used to pilot materials in Experiment 1 (i.e., select the correct statement from opposing sentence pairs and circle response certainty). Performance scores were used to (a) confirm that experimental materials contained information that was inconsistent with most students' existing beliefs and, (b) provide an individual-difference learning measure for these facts following study (i.e., pretest versus posttest comparison).

Subjects

The participants were 40 6th-grade students (14 males, 26 females, M = 11.0 years SD = .60 years) and 40 7th-grade students (17 males, 23 females, M = 12.0 years SD = .45 years) attending four public schools. Participation criteria were the same as in Experiment 1, with all students completing the pretest questionnaire. Ten participants from each grade were randomly assigned to one of four experimental conditions: activated elaborative interrogation, nonactivated elaborative interrogation, activated reading control, and nonactivated reading control.

Materials

Two sets of 32 factual statements similar to those used in Experiment 1 were used in this study. Half of the statements were consistent with students' prior knowledge, whereas the remaining statements were inconsistent with their beliefs. All statements were written in traditional text.

Procedure

Activation

To start the experimental session, students participated in a "warm up" activity. Each student was presented four titles. For subjects assigned to the activation conditions, the headings corresponded with the four to-be-learned content areas (solar system, circulatory system, plants, and animals). For the remaining subjects, the topic headings were about four unrelated topics (natural disasters, pollution, water, and Canada). Students were given 1.5 minutes to generate a conversation about each topic. They were instructed to talk about the first things that came to mind, reflecting on information that they had acquired in their classes, readings, and everyday experiences.

Study

Study instructions were identical to those used in Experiment 1. All students were told that they would see several statements about four topics, and that they would be asked about this information. Elaborative-interrogation subjects were instructed to read each statement silently and to answer why each fact is true. These students were instructed to use relevant prior knowledge to help them answer the "why" questions. Reading-control subjects were instructed to read each statement aloud for the entire time that the sentence was presented. It was stressed that they should read the statements for meaning.

Subjects were provided with four practice items. The 32 to-be-learned statements were presented individually for 15 second intervals. Two presentation orders were constructed for each set of materials, with half the students in each grade and condition randomly assigned to one order.

Retention Tests and Posttest Interview

The retention measures that were used to assess learning in Experiment 1 were also used in this experiment (i.e., free and cued recall, immediate and 14-day recognition). In addition, the students completed 75-day and 180-day recognition tests. All students were asked to rate task difficulty using a 10-point scale (1 = very easy, 10 = very hard).

Results

As in Experiment 1, the primary analyses involved the recall and recognition data. Two independent raters analyzed the free and cued recall responses for consistency with study materials. They agreed on 98% of the classifications.

Subjects retention scores were converted into proportion correct, with mean proportions and standard deviations for each fact type listed in Table 4 as a function of experimental

Insert Table 4 about here

condition. A 2 (strategy) by 2 (activation) by 2 (fact) ANOVA was carried out, with repeated measurement on the last variable. Tukey's HSD approach was used for post hoc analyses ($p \leq .05$).

Learning Gains Due to Strategy

For both recall and recognition scores, there was a significant main effect for strategy [$F(1,76) \geq 50.31$, $p<.001$]. Elaborative-interrogation subjects retained more study facts than did reading-controls (smaller $q = 7.82$).

Elaborative-interrogation learning gains could not be attributed to more recall attempts. Free and cued recall error analysis revealed no differences in the generation of extraneous statements or inaccurate statements across the study conditions [extraneous statement $F(1,76) \leq 1.53$; inaccurate statement $F(1,76) \leq 1.64$].

Learning Gains Due to Fact Type

The main effect of fact was not significant for free recall [$F(1,76) = 1.30$] but was significant for cued recall [$F(1,76) = 10.90$ $p<.001$]. For cued recall, subjects recalled more belief-inconsistent facts than belief-consistent facts ($q = 4.67$, $p<.01$).

Across all the recognition measures, there were significant main effects of fact [$F(1,76) \geq 60.36$, $p<.001$]. The students identified more belief-consistent facts than facts that were belief-inconsistent ($q \leq 10.99$, $p < .01$).

Learning Gains Due to Activation

There was only one effect due to activation. For free recall, the activation by fact interaction was significant [$F(1,76) = 5.43$]. Instructions to activate information about unrelated facts facilitated acquisition of belief-consistent facts relative to instructions to activate prior knowledge about to-be-learned facts ($q = 4.41$, $p <.01$). Caution must be used when interpreting this interaction because students generated very few ideas that corresponded with to-be-learned content (M = 1 idea per topic).

Certainty Responses for Recognition Tests

The recognition certainty responses for both types of facts are listed in Table 5 as a function of experimental condition.

Insert Table 5 about here

For each recognition measure and fact type, a 2 (strategy) by 2 (fact) by 3 (activation) ANOVA with repeated measurement on the last two variables was carried out.

For the pretest score, the strategy by accuracy and strategy by certainty interactions were not significant. The accuracy by certainty interaction was significant [$F(2,156) = 46.19$, $p<.001$]. Students reported being either 100% or 50% certain about their incorrect responses more often than about their correct responses ($q \geq 13.15$, $p<.01$).

There were three-way interactions of strategy, accuracy, and certainty for each posttest recognition measure [$F(2,156) \geq 2.94$]. Elaborative-interrogation subjects identified more study statements with 100% certainty than did reading-controls ($q \geq 4.49$, $p<.01$). For facts that addressed inaccurate beliefs, reading-controls made more erroneous selections with 100% certainty than did elaborative-interrogation subjects ($q \geq 4.74$, $p<.01$).

Subjects' pretest and posttest recognition scores were analyzed for facts addressing common misbeliefs (i.e., elaborative-interrogation learning gains may be confounded because not all students held inaccurate beliefs about target information). Specifically, the number of instances where subjects answered items incorrectly at pretest, but correctly at posttest, were evaluated. Elaborative-interrogation subjects made greater pretest-to-posttest gains than did reading-control subjects [$F(1,78) \geq 8.16$, $q \geq 4.04$, $p<.01$].

Relationship Between Elaborative Interrogation Study Responses and Subsequent Learning

The same raters that scored elaborative-interrogation study responses in Experiment 1, scored Experiment 2 data. 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 of learning for adequate, inadequate, and no response items are listed in Table

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Insert Table 6 about here

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6. There was one significant difference. For cued recall, items answered adequately were retained better than items that were not answered (q = 3.51, p<.01).

Posttest Interview

Students rated task difficulty (1 = very easy, 10 = very hard) for each topic. There was a significant main effect for condition [$F(1,75)$ = 8.80, p<.01]. Elaborative-interrogation subjects rated their task more difficult than did reading-controls (elaborative-interrogation M = 5.67, reading-control M = 4.60, q = 3.52, p<.05). Reading-control subjects were also more likely to indicate that they were doubtful or surprised about the presented facts than were elaborative-interrogation subjects (54.16% versus 14.58% of the probes).

Summary

The results of Experiment 2 are in agreement with those of Experiment 1. (1) Instructions to use elaborative interrogation enhanced learning for all science facts relative to reading-control instructions. (2) The type of answer provided to the elaborative-interrogation "why" question did not affect learning. (3) There were significant recognition, but not recall, differences associated with fact type. Facts that were consistent with students' prior knowledge were better recognized than were facts inconsistent with this knowledge. (4) Activation instructions had little affect on retention, probably because students did not generate much information relating to the study facts when reacting to the prior knowledge activation prompt used in this study.

Discussion and Concluding Comments

Unlike other methods that have been developed to help students overcome their inaccurate beliefs (e.g., anchoring and bridging analogies: Brown & Clement, 1989; Clement et al., 1987; conceptual conflict plus accommodation: Nussbaum & Novick, 1982), elaborative interrogation is an effective learning adjunct that requires minimal resources from instructors. Even when students do not possess sufficient prior knowledge to answer the why-questions about new facts, or cannot express what they know, learning is facilitated relative to reading for understanding.

Elaborative-interrogation learning gains were durable, with performance scores maintained up to 6 months following study. In general, these learning gains were large (i.e., relative to the reading-control standard deviations; Hedges & Olkin, 1985). When retention scores were collapsed across texts 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).

Elaborative interrogation enhanced students' awareness of what they knew, increasing confidence for correct recognition decisions and decreasing confidence for incorrect selections. In contrast, reading-controls expressed great confidence in their incorrect selections, consistent with other studies in which people report much certainty in errant understanding (e.g., Pressley, Ghatala, Woloshyn, & Pirie, 1990).

Pressley et al. (1988) noted that elaborative interrogation forces greater attention to the truth value of facts than does simply reading them. Consistent with Pressley et al.'s (1988) observation, elaborative-interrogation students rarely expressed surprise or disbelief about the science statements. In contrast, reading-controls challenged the correctness of the to-be-learned information almost twice as often as elaborative-interrogation subjects, doing so for over one-third of the probe items.

Reading-control subjects made fewer attempts to reconcile discrepancies between their prior knowledge and the science information. This type of processing may account for some of the recall and recognition differences between elaborative-interrogation and reading-control subjects. Pressley et al. (1988) control participants often generated their own interferences for learning new facts by thinking about prior knowledge that was seemingly inconsistent with the study facts [e.g.,. That's surprising, I always thought that... (going on to state something inconsistent with the to-be-learned fact)]. Martin and Pressley (1991) demonstrated that thinking about how facts seem surprising or wrong undermines learning relative to considering why a fact is sensible as stated. In short, elaborative-interrogation instructions simultaneously force processing supportive of learning (i.e., thinking about prior knowledge consistent with presented facts) and prevent processing that would undermine learning (i.e., thinking about why the fact does not seem sensible based on prior knowledge).

While learners often comprehend science information presented in class, and perhaps even acknowledge that this information is inconsistent with their existing beliefs, the new knowledge is compartmentalized: Students seem to retain information acquired in class as separate from knowledge that they use in everyday life. Thus, information learned in class can be retrieved for unit tests and other academic activities, but students use their inaccurate beliefs on other occasions (Champagne et al., 1982; Roth, 1990). Such encapsulated knowledge is undesirable. True conceptual change can only occur when students use new scientific knowledge as they navigate the world (Posner, Strike, Hewson, & Gertzog, 1982; Champagne et al., 1982). By forcing students to activate prior knowledge that is supportive of new content, elaborative interrogation forces students to question the validity of their inaccurate beliefs. We believe that the uncertainty about prior beliefs produced by prior knowledge might do much to produce more robust, general understanding of the new scientific facts. Our future work will evaluate such general understandings. The studies presented here demonstrate that elaborative interrogation can promote short-term and long-term learning per se of facts that clash with prior knowledge. The challenge now is to determine if elaborative interrogation can improve general use of such new knowledge.

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Footnotes

[1]The fact by text interaction suggested that inverted refutational text and refutational text advantages over traditional text were restricted to the acquisition of facts that were consistent with students' prior knowledge ($q \geq 6.53$, $p<.01$). This interaction is not interpreted here because the multisample circularity assumption was not tenable, indicating a positively biased F test ($X^2 = .01$). The interaction was not significant when the Geisser-Greenhouse conservative F and adjusted F tests were used [critical $F(1,58) = 4.08$ and $F(1.78, 103.45) = 3.11$ respectively].

[2]In this initial analysis, there were indications that reading refutational text enhanced recognition of facts addressing inaccurate beliefs relative to reading either traditional text ($q = 3.27$, $p<.05$) or inverted refutational text ($q = 4.98$, $p<.01$). There was no significant difference between traditional text and inverted text ($q = 1.21$, $p>.05$). These effects are not interpreted because the multisample circularity assumption was violated (fact by text interaction, $X^2 = .01$). Interaction F values failed to reach significance when the Geisser-Greenhouse conservative F and adjusted F tests were used [critical $F(1,58) = 4.08$, $F(1.45, 84.41) = 3.97$ respectively].

[3]The initial analysis suggested that the refutational text advantage over traditional text ($q = 3.47$, $p<.05$) and inverted refutation text ($q = 4.67$, $p<.01$) applied only to reading-control subjects. Again, the multisample circularity assumption was not

tenable (strategy by text interaction, X^2 = .02), with interactive F values failing to reach significance when the Geisser-Greenhouse conservative F and adjusted F tests were used [critical $F(1,58) = 4.08$, $F(1.45, 84.41) = 3.97$ respectively].

Table 1

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

Condition	Items Inconsistent with Prior Knowledge			Items Consistent with Prior Knowledge		
	T[a]	R[b]	IR[c]	T[a]	R[b]	IR[c]
		Free Recall				
Elaborative-Interrogation						
M	.333	.317	.275	.250	.425	.242
SD	.159	.262	.201	.189	.229	.202
Reading Control						
M	.154	.208	.125	.133	.258	.150
SD	.156	.219	.171	.139	.241	.181
		Cued Recall				
Elaborative-Interrogation						
M	.783	.775	.733	.729	.842	.817
SD	.207	.273	.245	.189	.232	.270
Reading Control						
M	.471	.667	.533	.446	.583	.508
SD	.227	.240	.284	.268	.296	.297

(table continues)

Condition	Items Inconsistent with Prior Knowledge			Items Consistent with Prior Knowledge		
	T[a]	R[b]	IR[c]	T[a]	R[b]	IR[c]
	Immediate Recognition					
Elaborative-Interrogation						
M	.917	.925	.875	.946	.933	.992
SD	.115	.117	.157	.102	.112	.046
Reading Control						
M	.721	.850	.692	.851	.875	.825
SD	.251	.242	.291	.175	.225	.209
	14-Day Recognition					
Elaborative-Interrogation						
M	.858	.867	.775	.867	.908	.908
SD	.112	.170	.257	.109	.139	139
Reading Control						
M	.700	.750	.592	.813	.800	.733
SD	.199	.263	.297	.217	.289	.262

Note. *n* = 30 for each condition.

[a] Traditional text.

[b] Refutational text.

[c] Inverted Refutational text.

Table 2

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

	Correct Selections			Incorrect Selections		
	100% SURE	50% SURE	100% SURE	100% SURE	50% SURE	100% SURE
Immediate Recognition						
Facts Inconsistent with Prior Knowledge						
Elaborative Interrogation						
M	12.50	1.90	.10	.73	.70	.03
SD	2.79	1.99	.40	.91	.95	.18
%	78.13	12.08	.63	4.58	4.38	.21
Reading Control						
M	8.90	2.90	.17	1.53	2.13	.37
SD	4.41	2.63	.46	1.55	1.98	.85
%	55.63	18.13	1.04	9.58	13.33	2.29
Immediate Recognition						
Facts Consistent with Prior Knowledge						
Elaborative Interrogation						
M	13.43	1.77	.03	.28	.43	.07
SD	2.29	1.91	.18	.52	.57	.36
%	83.96	11.04	.21	1.67	2.71	.42
Reading Control						
M	10.23	3.23	.23	.57	1.43	.30
SD	4.35	2.46	.68	.77	2.08	.65
%	63.96	20.21	1.46	3.54	8.96	1.88

(table continues)

	Correct Selections 100% SURE	50% SURE	100% SURE	Incorrect Selections 100% SURE	50% SURE	100% SURE
14-Day Recognition Facts Inconsistent with Prior Knowledge						
Elaborative Interrogation						
M	10.67	2.90	.03	1.27	1.03	.10
SD	3.63	2.89	.18	1.31	1.22	.40
%	66.67	18.13	.21	7.92	6.46	.63
Reading Control						
M	7.07	3.10	.48	1.93	2.63	.27
SD	4.54	2.91	1.50	1.95	2.16	.64
%	45.69	20.04	3.01	12.50	17.03	1.72
14-Day Recognition Facts Consistent with Prior Knowledge						
Elaborative-Interrogation						
M	11.73	2.40	.10	1.07	.70	.00
SD	2.84	2.45	.40	1.08	.95	.00
%	73.33	15.00	.63	6.67	4.38	.00
Reading Control						
M	7.57	3.93	.58	1.30	1.87	.23
SD	5.24	3.59	1.72	2.26	1.81	.43
%	48.92	25.43	3.66	8.41	12.07	1.51

Note. *n* = 30 for each condition.

Table 3

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

Type of Test	Conditional Adequate Probability	Conditional Inadequate Probability	Conditional No Response Probability
		Free Recall	
M	.317	.304	.268
SD	.161	.136	.317
n	30	30	20
		Cued Recall	
M	.683	.660	.661
SD	.114	.126	.308
n	30	30	20
		Immediate Recognition	
M	.972	.916	.829
SD	.048	.072	.315
n	30	30	20
		14-Day Recognition	
M	.905	.842	.858
SD	.105	.096	.195
n	30	30	20

Table 4

Means and Standard Deviations for Free Recall, Cued Recall, Immediate, 14-Day, 75-Day, and 180-Day Recognition as a Function of Experimental Condition, Activation, and Fact Type: Experiment 2

	Facts Inconsistent with Prior Knowledge		Facts Consistent with Prior Knowledge	
Condition	Activation	Nonactivation	Activation	Nonactivation
	Free Recall			
Elaborative-Interrogation				
M	.288	.284	.206	.284
SD	.132	.102	.111	.112
Reading Control				
M	.128	.141	.109	.175
SD	.085	.090	.090	.092
	Cued Recall			
Elaborative-Interrogation				
M	.838	.791	.734	.747
SD	.104	.115	.111	.126
Reading Control				
M	.584	.538	.497	.503
SD	.135	.222	.202	.184

(table continues)

Condition	Facts Inconsistent with Prior Knowledge: Activation	Facts Inconsistent with Prior Knowledge: Nonactivation	Facts Consistent with Prior Knowledge: Activation	Facts Consistent with Prior Knowledge: Nonactivation
Immediate Recognition				
Elaborative-Interrogation				
M	.913	.878	.984	.959
SD	.082	.094	.028	.058
Reading Control				
M	.722	.753	.844	.916
SD	.174	.181	.174	.110
14-Day Recognition				
Elaborative-Interrogation				
M	.853	.822	.947	.931
SD	.122	.089	.047	.078
Reading Control				
M	.659	.716	.828	.844
SD	.156	.181	.152	.140
75-Day Recognition				
Elaborative-Interrogation				
M	.750	.747	.903	.850
SD	.133	.114	.059	.168
Reading Control				
M	.566	.581	.784	.781
SD	.195	.160	.150	.155

(table continues)

Condition	Facts Inconsistent with Prior Knowledge Activation	Facts Inconsistent with Prior Knowledge Nonactivation	Facts Consistent with Prior Knowledge Activation	Facts Consistent with Prior Knowledge Nonactivation
180-Day Recognition				
Elaborative-Interrogation				
M	.723	.750	.878	.852
SD	.098	.138	.087	.164
Reading Control				
M	.507	.516	.714	.783
SD	.174	.234	.164	.161

Note. n = 40 for each condition (free recall through 75-delayed recognition).

Note. For 180-day recognition: elaborative-interrogation n=39 reading-control n = 38.

Table 5

Certainty Ratings for Immediate, 14-Day, 75-Day and 180-Day Recognition as a Function of Experimental Condition and Fact Type: Experiment 2

	Correct Selections			Incorrect Selections		
	100% SURE	50% SURE	100% SURE	100% SURE	50% SURE	100% SURE
Pretest Recognition						
Facts Inconsistent with Prior Knowledge						
Elaborative Interrogation						
M	1.95	2.50	.30	5.98	4.78	.50
SD	1.45	1.70	.61	2.69	2.55	.82
%	12.19	15.63	1.88	37.34	29.84	3.13
Reading Control						
M	1.50	2.33	.63	5.45	5.43	.68
SD	1.66	1.75	.98	3.25	2.85	1.02
%	9.38	14.53	3.91	33.75	34.22	4.22
Immediate Recognition						
Facts Inconsistent with Prior Knowledge						
Elaborative-Interrogation						
M	11.85	2.33	.03	.93	.80	.08
SD	2.97	2.65	.12	.94	1.04	.27
%	74.06	14.53	.16	5.78	5.00	.47
Reading Control						
M	9.43	1.63	.65	2.30	1.85	.15
SD	4.06	1.75	2.39	1.79	1.90	.80
%	58.91	10.16	4.06	14.38	11.56	.94

	Correct Selections 100% SURE	50% SURE	100% SURE	Incorrect Selections 10^% SURE	50% SURE	100% SURE
Immediate Recognition						
Facts Consistent with Prior Knowledge						
Elaborative-Interrogation						
M	12.70	2.03	.45	.28	.10	.50
SD	3.94	2.57	1.90	.50	.30	.15
%	81.41	12.98	2.88	1.76	.64	.32
Reading Control						
M	10.95	1.98	.68	.60	1.10	.30
SD	4.35	1.71	1.98	.95	1.52	1.34
%	70.19	12.66	4.33	3.85	7.05	1.92
14-Day Recognition						
Facts Inconsistent with Prior Knowledge						
Elaborative-Interrogation						
M	10.65	2.63	.13	1.23	1.28	.10
SD	3.75	2.61	.52	1.23	1.15	.30
%	66.56	16.41	.78	7.66	7.97	.63
Reading Control						
M	8.28	2.48	.25	2.98	1.85	.18
SD	3.36	2.16	.84	2.53	1.81	.45
%	51.72	15.47	1.56	18.59	11.56	1.09

(*table continues*)

	Correct Selections			Incorrect Selections		
	100% SURE	50% SURE	100% SURE	100% SURE	50% SURE	100% SURE
14-Day Recognition						
Facts Consistent with Prior Knowledge						
Elaborative-Interrogation						
M	12.15	2.18	.55	.48	.50	.03
SD	3.71	2.28	.66	.61	.87	.11
%	77.88	13.94	1.76	3.04	3.21	.16
Reading Control						
M	9.80	2.88	.30	1.23	1.18	.26
SD	4.49	2.64	.69	1.32	1.68	.47
%	62.82	18.43	1.92	7.85	7.53	1.44
75-Day Recognition						
Facts Inconsistent with Prior Knowledge						
Elaborative-Interrogation						
M	8.08	3.28	.53	1.53	2.23	.38
SD	3.56	2.09	1.40	1.41	2.07	1.23
%	50.47	20.47	3.28	9.53	13.91	2.34
Reading Control						
M	5.65	2.78	.40	3.18	3.15	.53
SD	3.28	1.76	1.01	2.60	2.42	1.45
%	36.04	17.70	2.55	20.26	20.10	3.35

(table continues)

	Correct Selections 100% SURE	50% SURE	100% SURE	Incorrect Selections 100% SURE	50% SURE	100% SURE
75-Day Recognition						
Facts Consistent with Prior Knowledge						
Elaborative-Interrogation						
M	10.20	3.38	.55	.98	.70	.20
SD	4.32	3.00	1.41	1.07	.98	.60
%	63.75	21.09	3.44	6.09	4.38	1.25
Reading Control						
M	7.83	3.90	.78	1.03	1.65	.43
SD	3.94	2.58	1.53	1.09	1.59	.85
%	50.14	24.99	4.97	6.57	10.58	2.72
180-Day Recognition						
Facts Inconsistent with Prior Knowledge						
Elaborative-Interrogation						
M	7.60	3.45	.48	1.70	2.03	.35
SD	4.06	2.70	1.15	1.91	1.94	.77
%	48.72	22.12	3.04	10.90	12.98	2.24
Reading Control						
M	4.73	2.55	.53	3.45	3.70	.25
SD	3.67	2.60	1.06	3.03	2.78	.67
%	31.09	16.78	3.45	22.70	24.34	1.64

(table continues)

	Correct Selections 100% SURE	50% SURE	100% SURE	Incorrect Selections 100% SURE	50% SURE	100% SURE
			180-Day Recognition			
			Facts Consistent with Prior Knowledge			
Elaborative-Interrogation						
M	9.33	3.33	.50	.78	1.00	.28
SD	4.77	3.06	.88	1.26	1.49	.65
%	62.26	21.49	3.00	1.78	6.46	5.01
Reading Control						
M	6.90	3.78	.68	1.23	2.15	.48
SD	4.19	3.28	1.17	1.57	2.06	1.04
%	45.39	24.84	4.44	3.13	14.14	8.06

Table 6

Answers Provided to Why Questions and Conditional Probabilities for Free Recall, Cued Recall, Immediate, 14-Day, 75-Day and 180-Day Recognition as a Function of Answer Type: Experiment 2

Type of Test	Conditional Adequate Probability	Conditional Inadequate Probability	Conditional No Response Probability
		Free Recall	
M	.268	.258	.216
SD	.131	.150	.243
n	40	40	24
		Cued Recall	
M	.800	.760	.660
SD	.091	.146	.343
n	40	40	24
		Immediate Recognition	
M	.928	.934	.902
SD	.080	.074	.281
n	40	40	24
		14-Day Recognition	
M	.884	.888	.898
SD	.091	.116	.229
n	40	40	24

(table continues)

Type of Test	Conditional Adequate Probability	Conditional Inadequate Probability	Conditional No Response Probability
75-Day Recognition			
M	.831	.799	.809
SD	.097	.141	.263
n	40	40	24
180-Day Recognition			
M	.776	.754	.721
SD	.208	.204	.346
n	40	40	24

Appendix A

Experimental Materials

Solar System

1. In space, the sun's heat cannot even roast a potato.
(Inconsistent with Prior Knowledge, Traditional Text)

2. Although some people think that the size of a star is always the same, the size changes.
(Consistent with Prior Knowledge, Refutational Text)

3. Moon soil is made up of small pieces of rock and glass.
(Consistent with Prior Knowledge, Traditional Text)

4. Oxygen is not the same as air.
(Inconsistent with Prior Knowledge, Traditional Text)

5. The distance between the earth and the moon changes everyday, although some people think that it is always the same.
(Consistent with Prior Knowledge, Inverted Refutational Text)

6. Although some people think that the light of the sun is only red or yellow, it is made of every different colour including blue and violet.
(Inconsistent with Prior Knowledge, Refutational Text)

7. Stars are gases, although some people think that they are solid.
(Inconsistent with Prior Knowledge, Inverted Refutational Text)

8. The largest known volcano is on the planet Mars.
(Consistent with Prior Knowledge, Traditional Text)

Plants

9. New plants can grow from roots, stems, and leaves.
(Consistent with Prior Knowledge, Traditional Text)

10. Although some people think that plants always need light, plants do not always need light.
(Inconsistent with Prior Knowledge, Refutational Text)

11. Maple keys and milkweed pods are fruits, although some people do not think that they are.
(Consistent with Prior Knowledge, Inverted Refutational Text)

12. Plants do not get food from the soil.
(Inconsistent with Prior Knowledge, Traditional Text)

13. Not all plants have roots, although some people think that all plants have them.
(Inconsistent with Prior Knowledge, Inverted Refutational Text)

14. Although some people do not think that all human food comes from green plants, all human food originally comes from plants.
(Consistent with Prior Knowledge, Refutational Text)

15. In plants, food travels from the leaves to the roots.
(Inconsistent with Prior Knowledge, Traditional Text)

16. The soil provides plants with oxygen.
(Consistent with Prior Knowledge, Traditional Text)

Animals

17. There are more animals without backbones than animals with backbones.
(Inconsistent with Prior Knowledge, Traditional Text)

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.
(Consistent with Prior Knowledge, Refutational Text)

19. Worker bees dance to tell each other where there is food, although some people think that they buzz.
(Inconsistent with Prior Knowledge, Inverted Refutational Text)

20. Rattlesnakes have small scales on their heads.
(Consistent with Prior Knowledge, Traditional Text)

21. Although some people do not think that lost of animals and birds eat rattlesnakes, many animals and birds eat them.
(Inconsistent with Prior Knowledge, Refutational Text)

22. Earthworms need to be in the soil to breathe, although some people think that they can breathe anywhere.
(Consistent with Prior Knowledge, Inverted Refutational Text)

23. Earthworms come in many different colours including brown, green, and purple.
(Inconsistent with Prior Knowledge, Traditional Text)

24. Bees often dig small holes in the ground.
(Consistent with Prior Knowledge, Traditional Text)

Circulatory System

25. The heart pumps both blood with oxygen and blood without oxygen.
(Inconsistent with Prior Knowledge, Traditional Text)

26. Although some people think that blood cells last for a lifetime, new red blood cells are needed about every four months.
(Consistent with Prior Knowledge, Refutational Text)

27. There are four main types of blood.
(Consistent with Prior Knowledge, Traditional Text)

28. Respiration is not the same as breathing, although some people think that they are the same.
(Inconsistent with Prior Knowledge, Inverted Refutational Text)

29. Pus is white blood cells that have died.
(Consistent with Prior Knowledge, Traditional Text)

30. Although some people think that the heart makes and stores blood, its only function is to pump blood.
(Inconsistent with Prior Knowledge, Refutational Text)

31. Some living things have only one cell.
(Inconsistent with Prior Knowledge, Traditional Text)

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.
(Consistent with Prior Knowledge, Inverted Refutational Text)