ELABORATIVE INTERROGATION AND
COGNITIVE STRUCTURE

by

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Ph.D., Simon Fraser University, 1992

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
in the department
of
EDUCATION

SIMON FRASER UNIVERSITY
March 1992

ISBN 0-315-83722-5

APPROVAL

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Degree: Doctor of Philosophy

Title of Thesis: Elaborative Interrogation and Cognitive Structure

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ELABORATIVE INTERROGATION AND COGNITIVE STRUCTURE

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Abstract

Previous research has identified elaborative interrogation as an effective strategy for aiding memory for information. In this study, 114 grade six and seven students participated in two sessions. In the first session students read a passage describing five biological principles of adaptation. In the second session, students read a passage describing the characteristics and behaviours of three animals. Students were randomly assigned to one of four groups for the second session. Students in the underline only group were asked to read each paragraph in the passage and underline the most important idea in the paragraph. Students in the second group, the generate elaboration group, read each paragraph and were asked to answer a *why* question about the main idea of the paragraph. Students in the elaborate with study sheet group also answered a *why* question, but had access to a study sheet with information on it to help them answer the question. Students in the underline and elaborate group read the same base paragraph, but each paragraph had an extra sentence linking the main idea of the paragraph to the principle of adaptation read in the first session.

Measures consisted of motivation rating scales, an associative memory task, short answer questions probing the links between the target fact from each paragraph in the second session to the rule from the first session, an inference question, and a problem-solving question.

Data analyses consisted of between groups contrasts and conditional probabilities. Results showed the students to rate motivation for the tasks in a positive manner. The results also showed the generate elaboration group to outperform the underline only group on the associative memory task, while the other two elaboration groups did not. Performance of the elaboration groups was not superior to the underline only groups on the inference task and problem-solving task. Conditional probabilities showed that memory for the target fact was enhanced by creating links between the target fact and the appropriate principle of adaptation. These results suggest that elaborative interrogation works by creating links between new information and prior knowledge.

Acknowledgements

The production of a piece of work such as a dissertation is seldom a process that is performed in isolation. It cannot be produced without the assistance and advice of several important people. The author is indebted to those people.

First, a study about human learning must involve humans. A gesture of thanks is extended to the students and teachers of the two districts participating in the study. Their time and cooperation is most appreciated.

Second, there are the members of the examining committee. Their wisdom and insight has proven valuable, and their comments have helped strengthen my study and provide direction for future research.

Third, there is Dr. Winne. Mentor, advisor, and friend, his expertise, counsel, and insight have guided my path. It is with gratitude, respect, and pride that I thank him for all he has done for me over the years. I hope that some day I may do the same.

A special note of thanks is extended to Steve Lydiat for his help in collecting data. Without his help, the collection of data would have been postponed for several months.

Lastly, I must point out the the love and support of my wife and two sons have been the driving inspiration of my success. Words cannot express the importance of their contribution, now and for the future.

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Chapter 1: The Promise of Elaborative Interrogation

One of the primary aims of education is to help students become good problem solvers and critical thinkers, and gain an understanding of the content domains that are taught. In the domain of science, this understanding would partially consist of being able to state a principle, and being able to recognize instances of the principle in natural settings. That is, we would want the student to transfer his or her knowledge.

The ability to transfer and solve problems relies upon a highly integrated and interconnected cognitive structure (see Prawat, 1989; de Jong & Fergusson-Hessler, 1986). Research suggests that experts and novices differ in the ways in which their knowledge is organized. To promote problem solving and transfer, cognitive structure should be highly organized and interconnected. So when a student learns new information that is to help in solving problems, the learner must impose an organization on it by building internal connections between ideas in the new information. Simultaneously, the learner must build external connections between the new information and prior knowledge. The result is a cohesive chunk of knowledge that is highly integrated with other knowledge and is accessible during problem solving tasks.

Research also suggests ways to promote building these connections. The use of learning strategies such as summarizing or paraphrasing, outlining, networking, or using text structures provide ways for students to build internal connections. By using these strategies students are able to comprehend new information by organizing the ideas.

To build external connections the student needs to relate the new information to existing knowledge. This can be accomplished by engaging in elaboration strategies. These elaboration strategies include generating new examples, using analogies, generating images, comparing or contrasting the new information with something they already know, or asking questions that involve making inferences.

The usefulness of elaboration as a means for enhancing problem-solving has been demonstrated in several studies. Hamilton (1989) gave undergraduate students a passage describing four psychological concepts. Hamilton found that students who generated their own examples of the psychological concepts were better problem-solvers. Of particular interest is the ability-treatment interaction found by Hamilton in which low ability students in the elaboration condition (measured by a reading efficiency test and a mental skills test) performed as well as high ability students in the elaboration condition and high-ability students who did not elaborate.

A study by Wittrock and Alesandrini (1990) had students read a 5200 word passage on sea life. Wittrock and Alesandrini found that students who generated summaries or analogies as they read outperformed students who used repetition on the post-test measure of learning. Hence, generating analogies served as an effective way of boosting achievement. Elaboration may be a knowledge-acquisition strategy that is particularly useful for poor readers.

One well-researched technique for getting students to elaborate is to ask them *why* questions. For example, if a student reads a fact such as *The first apples grown in Canada were grown in Nova Scotia.* and is required to answer the question *Why were the first apples grown in Nova Scotia?* the student must make inferences to answer questions. The result is that the student will be more likely to remember the fact than if he did not try to answer the question (Pressley, Symons, McDaniel, Snyder, & Turnure, 1988). When trying to think of an answer, presumably the student must connect the new information to prior knowledge and the fact is made more memorable.

The effectiveness of elaborative interrogation has been demonstrated across a wide range of age groups and topics. The finding has been shown to be robust with undergraduates (Pressley et al, 1988; Pressley, McDaniel, Turnure, Wood, & Ahmad, 1987) and elementary school children (Wood, 1989). Materials have covered a variety of topics including animal behaviour (Wood, 1989), gender differences (Pressley et al., 1988), and facts about universities (Woloshyn, Willoughby, Wood, & Pressley, 1990). As such, the strategy has potential as a simple and effective way of helping students learn more.

While a great deal of research has been conducted, several important questions remain to be answered about elaborative interrogation. Two of these include:

Is elaborative interrogation an effective strategy when used in a more sophisticated and coherent reading context than examined in previous research?

What role does prior knowledge play in elaborative interrogation?

Prior research examining the effectiveness of elaborative interrogation has been demonstrated within a constrained set of reading materials. In such studies (Pressley et al., 1988; Pressley et al., 1987; Woloshyn et al., 1990) students in a comparison or control group read a set of facts. Students in the experimental group read the same set of facts but were instructed to engage in elaborative interrogation. Although such studies demonstrated that elaborative interrogation was effective on recall and recognition tasks, the facts to be learned by students in such studies were not representative of a typical reading task. The facts tended to be unconnected and lacked any significant structure within the ideas. For example, students read sentences such as *The hungry man got into the car.* and *The toothless man wrote a cheque.* A typical expository prose passage is rich in context and contains a structure which holds the ideas together. Is elaborative interrogation still effective within such a reading context?

On the one hand, we might expect elaborative interrogation to still be effective. Previous studies used sentences such as *The hungry man got into the car.* We must recognize that such a sentence is not void of context. If students generate an answer to a *why* question they must make inferences and in doing so, create a context into which the fact may be placed. Hence the cognitive operation of inferring the relationship between an object (the hungry man), the attribute (hungry), and the action (got into the car) would be identical to the inferences that may be made during the course of selecting a main idea from a paragraph and generating an answer to a why question about that main idea.

On the other hand, the richer context provides opportunity for effects to arise which may mask the effectiveness of elaborative interrogation. In the course of reading a paragraph, students engage in several strategies, such as locating the main idea, which may reduce the apparent effectiveness of elaborative interrogation. The paragraph itself consists of a main idea with supporting details. The supporting details might be considered elaborations of the main idea and may influence the effectiveness of elaborative interrogation. Additionally, there is an epistemological consideration in the sense that the main idea is embedded within a knowledge domain, and the mental model the learner invokes to generate the elaboration may be of paramount importance. Under such conditions, will elaborative interrogation enhance learning to the degree reported in previous studies?

Why do we need to think about elaboration? Research suggests that normal readers have adequate organization strategies and spontaneously use them, but they may not spontaneously elaborate (Wong, 1979). If this is the case, then we need to consider two possibilities: a) we need to make provisions for cueing students to engage in elaboration; b) we need to provide instruction in the use of elaboration strategies to enable students to engage in elaboration.

Elaborative techniques such as elaborative interrogation are thought to assist learners in developing integrated and efficient cognitive structures. Prior research has demonstrated that the way in which the learner processes information influences learning (Schuell, 1990). When encountering new information, learners often rely upon memorization which leads to a poorly integrated cognitive structure. Performance involving verbatim knowledge is good, but problem-solving is poor. But as the learner's cognitive structure becomes more efficiently organized performance on tests involving principles, concepts, and problem-solving improves (Bromage & Mayer, 1986; Mayer, 1983). Utilizing learning strategies, such as elaborative interrogation, is thought to influence the way in which learners organize their cognitive structure. It helps them create the organized and efficient structures necessary for good problem solving performance.

The ultimate goal of research into elaborative interrogation is to create a viable study skill for students. Often, psychological research is conducted in the context of highly constrained and artificial conditions, but the findings are transferred into richer contexts. For example, results from early list learning studies have identified cognitive processes such as chunking and rehearsal as aids to remembering lists of items. Subsequently, such ideas are applied to richer contexts (Mayer, 1987).

Another example is the use of mnemonics. Mnemonic techniques originally developed out of paired-associate research. However, the use of mnemonics as a study skill is recognized and advocated widely, as indicated by a sampling of introductory educational psychology textbooks.

Elaborative interrogation has reached the threshold of being advocated as a study skill. Previous research has used highly constrained and artificial materials, and has examined the effectiveness of elaboration on paired-associates and list learning. However, a threshold has been reached and the opportunity now exists to carry elaborative interrogation beyond limited psychological paradigms to a context that is similar to the manner in which students might use it.

The path to carry elaborative interrogation over such a threshold would involve two steps. First, it would examine the effectiveness of elaborative interrogations under conditions that students would encounter in their normal course of study. This step would involve examining how elaborative interrogation might be used in the course of a normal reading passage, and how it might interact with other strategies. Second, it would involve teaching students to use elaborative interrogation as a self-questioning strategy on their own. This would involve finding ways of teaching students to generate their own questions and examining ways in which students can effectively use elaborative interrogation.

This study intends to take the first step on the path to using elaborative interrogation as a study skill. Consequently it has two immediate purposes. The first is to examine the use of elaborative interrogation in a context previously not reported. Previous studies investigating elaborative interrogation have used contrived materials that are not representative of materials that many students would encounter in the course of their learning. Previous studies have used materials that consisted of arbitrary, disconnected facts rather than facts that are related to each other, as is the case in an expository passage.

Second, previous studies have focussed upon two achievement variables: the number of facts that could be recalled and measures of recognition. The results of this research yield the uncontested conclusion that elaborative interrogation increases memory for facts. Previous studies have also reported that the explanatory power of the elaboration is not an important factor affecting learning. However, in a context that is rich, such as science, the mental model used to generate the elaboration may be of importance, particularly if the learner is asked to solve novel problems. Additionally, no evidence to date has been provided to suggest that elaborative interrogation serves to create relationships between newly acquired information and prior knowledge.

This study serves to address these two shortcomings by creating a richer context and examining several different achievement variables. Students in this study read paragraphs describing the behaviours and characteristics of animals. The main idea of each paragraph was illustrative of a scientific principle of adaptation. As they read, students either elaborated the main idea or underlined it.

Having completed the readings, students were measured on a series of variables including measures of associative learning (a recognition task), assembly of links between newly acquired information and prior knowledge, memory for details, and problem-solving.

This experimental design allows two research questions to be addressed:

1) Does elaborative interrogation lead to greater learning when used in a rich reading context representative of a content domain?
2) Does elaborative interrogation lead to the creation of relationships between newly acquired information and prior knowledge? Is the relationship itself an important consideration for learning?

Chapter 2: The Nature of Elaborative Interrogation

The view of humans as information processors has led to the development of cognitive models of learning (Weinstein & Mayer, 1986; Winne, 1985). In these models, learning occurs when students are able to engage in cognitive processes such as elaboration. They mentally manipulate information in particular ways to create understanding.

One model of cognitive processing postulates five different cognitive processes: attending, retrieving, organizing, elaborating, and monitoring (Weinstein & Mayer, 1986). Of immediate concern to this study are the processes of organizing and elaborating. Learning, according to this model, occurs when students are able to engage in organizing and elaborating strategies. Organization strategies are used to build internal connections. According to Mayer, building internal connections refers to establishing relationships between ideas wholly contained within the to-be-learned information. Elaboration strategies are used to build external connections, which is the act of establishing relationships between ideas in the to-be-learned material and things the learner already knows. By engaging in such activities the learner builds an integrated network of ideas.

A second model of cognitive processing also posits five cognitive processes: stimulating, monitoring, assembling, rehearsing, and translating (Winne, 1985). There is some overlap between Weinstein and Mayer's model and Winne's model. Both acknowledge that learning involves cognitive processing of information, and that the organization and integration of information is a necessary condition for learning. However, Winne's model presents two important features not readily present in the Weinstein and Mayer model. First, Winne's model explicitly suggests the possibility of multiple encodings of information through a translation process. Information may be encoded in several different forms such as semantic and imaginal. A student could have a semantic representation of an object that might include its name, shape, colour, and other attributes. The learner could also possess a mental image of the object. The same object is represented in two different ways.

Second, Winne's model does not distinguish between organization and elaboration as Weinstein and Mayer do, but refers to both as an instance of assembly. This lack of distinction is important because Weinstein and Mayer's distinction presents a problem. According to Weinstein and Mayer elaboration occurs when new ideas are related to prior knowledge. Organization occurs when ideas in the new information are related to each other. The problem with Weinstein and Mayer's definition is that learning sequential, and the definition of what is prior knowledge becomes gray. Hence, knowing whether a student is using organization or elaboration becomes uncertain.

For example, suppose a student is reading a passage about the snowshoe hare. The student reads a sentence that states the snowshoe hare turns white in winter. The student may recall that the Arctic fox is also white in winter and note this similarity. The student has engaged in elaboration by relating the new information to something he already knew.

Suppose the student then reads that the snowshoe turns white because this affords a means of protection. The student connects the idea of protection to the characteristic of the animal. Under Weinstein and Mayer's definition, this might be considered organization because the student has related two pieces of new information together. But is it really new information? By the time the student reads the fact about protection, the student already knows the snowshoe hare changes colour in winter. This makes the characteristic of the hare prior knowledge. If so, then the student has engaged in elaboration rather than organization. The key question is, *At what point is information prior knowledge?* Is information that has just been transferred to short-term memory new information or prior knowledge?

Of course, one could argue that the question of what constitutes prior knowledge and new knowledge is trivial, and that the really important issue is that the learner must engage in some sort of cognitive activity to build relationships. Admittedly, this is a very good point which begs the question why make the distinction in the first place.

The model posited by Winne side-steps this issue. Winne suggests that organization and elaboration are instances of an assembly operation. Assembly is a cognitive operation which involves creating relationships between ideas. The student assembles relationships between bits of information to create a cognitive structure. Different sources of information may be used for assembly. Some information comes from short-term memory, some from external sources such as a reading passage. Elaboration, in Winne's view, is an instance of connecting new information with information already in memory, or between two bits of information in memory. The distinction between new information and prior knowledge is less important.

The distinction between internal and external connections, and consequently between organization and elaboration, is blurred when considering the definition of elaboration used by researchers investigating elaboration. A review of the literature quickly shows the definition of elaboration to be any information that clarifies the relationship between two concepts (Hamilton, 1989). Early researchers investigating elaboration used a methodology that compared groups of students reading base sentences or base sentences plus an elaboration (Stein, Littlefield, Bransford, & Persampieri, 1984). In such studies, the elaboration read by students consists of a phrase which clarified the relationship between two referents in the base sentences. For example, a base sentence might be *The funny man bought a ring.* The base sentence plus elaboration might read *The funny man bought a ring that squirted water* (Stein et al., 1984). The elaboration *squirted water* clarifies the relationship between the man and the ring and adds meaning to the base sentence. The elaboration was provided to the students, rather than having students generate the relationship.

In later studies, elaboration is defined as information provided by the learner that create a relationship between the two referents. In such studies, students read a base sentence and were asked to provide an elaboration (Stein & Bransford, 1979; Pressley, McDaniel, Turnure, Wood, & Ahmad, 1987). For example, students might read *The funny man bought a ring* and be asked the explain why the funny man would by a ring. In such studies the students generate the elaboration which clarifies the relationship between the funny man and the ring. In such an instance, the student must rely upon prior knowledge for the elaboration, rather than reading the elaboration as part of the text.

If these two definitions of elaboration are acceptable, this raises the question what is the difference between organization and elaboration, as described in the Weinstein and Mayer model? What is the difference between building internal and external connections? Or does such a distinction matter?

In Winne's model, the distinction between internal and external connections is not important. Both are an instance of assembly, and it is through assembly that learning occurs. Hence, the learner can assemble links between ideas all contained within the text, (such as in the case of reading the referents in the base sentences and the elaboration). Additionally, the learner can assemble links between ideas contained in the text and prior knowledge (such as in the case of reading the referents in a base sentence and generating an elaboration). Viewing both as instances of assembly sidesteps the fuzzy distinction between internal and external connections. The issue becomes one of determining the types of assemblies a particular learning strategy might lead students to make, and assessing the effectiveness of such a strategy on learning.

Prior Research on Elaborative Interrogation

The act of assembling information is performed when executing learning strategies. To successfully execute the learning strategy should create an assembly. For example, if the learner read the fact *The snowshoe hare turns white in winter.* and were to answer a question such as *Why does the snowshoe hare turn white in winter?* the student would be required to: (a) retrieve a schema or model explaining why animals would need to change colour, and (b) assemble links between the existing schema and the new fact. Such a strategy is called elaborative interrogation.

The use of elaboration as a means of enhancing recall is a well established finding in psychological research. Early studies showed that when facts are elaborated by adding clarifying content or generating inferences, retention of the facts is enhanced (Pressley et al., 1987; Stein et al., 1982). These studies showed that when a fact such as *The hungry man got into the car* is elaborated by *to go to the restaurant* the initial fact is made more memorable. The studies by Pressley et al. (1987) and Stein et al. (1982) showed that when students generate their own elaborations, recall is enhanced more than if the elaborations are provided. Using this finding, Pressley has demonstrated that asking students *why* questions, such as, *Why did the hungry man get into the car?* prompts students to generate elaborations of the initial fact which makes the fact more memorable.

The effectiveness of elaborative interrogation as an aid to remembering facts has been demonstrated many times across a wide range of age groups and topics. Pressley et al.

(1987, experiment 1) had university students read a set of 24 sentences. Each sentence described a man performing some action. For example:

The ugly man bought some plastic.
The toothless man wrote a check.
The strong man carried a shovel.

One group of students read these sentences. A second group read the sentences and an elaboration of the sentence. The third group, the elaborative interrogation group, read the sentence and were asked *Why did that particular man do that?* A memory test consisting of 24 questions asking which man performed some action, such as *Which man bought some plastic?*, was administered to all groups. Results showed that the elaborative interrogation group outperformed the other two groups. Similar results are reported by Wood (1989, experiment 1) using elementary age students.

In another study, Pressley et al. (1988, experiment 3) repeated the experiment with a different set of facts. Three groups of university students read a set of 36 facts about Canada, such as *British Columbia is the province with the highest percentage of its population in unions.* One group read the facts. The second group was asked to create a visual image to represent the fact. The third group read the facts and was asked to answer a *Why* question - *Why would British Columbia be the province with the largest population in unions?* Students were then given a memory test. Results showed that students in the elaborative interrogation group outperformed the reading control group. A replication of this study (Pressley et al., 1988, experiment 4) used facts about gender differences. Students read facts such as *Men have slower pulse rates than women.* Again, results showed that elaborative interrogation enhanced recall in comparison to the reading control group.

There are at least two hypotheses to explain the success of elaborative interrogation. The first hypothesis, which may be called the attention hypothesis, suggests that elaborative interrogation requires the learner to focus on the fact that is presented (Pressley et al., 1988). This hypothesis suggests that elaborative interrogation forces students to attend to the fact which leads to greater learning.

This hypothesis is insufficient and seems to lack explanatory power. Although it may be the case that attention is a necessary condition for learning, it seems to be insufficient.

Given the models of learning posited by Weinstein and Mayer, and Winne, it seems unlikely that attention is a cognitive process that functions in isolation, and it seems unlikely that it alone is sufficient for learning. A suitable mechanism for explaining the phenomenon seems to be missing and alternative explanations are possible. It may be the case that students who attend to the facts are more likely to engage in rehearsal or elaborative strategies necessary to produce learning. Some other mechanism is needed.

A second hypothesis, which may be called the learning strategy hypothesis (Mayer, 1980) or the generation hypothesis, suggests the success of asking *why* questions centres upon the fact that students are able to relate the new information to something that they already know (Mayer, 1980; Pressley et al., 1988; Wittrock & Alesandrini, 1990; Wittrock, 1989; Wittrock, 1986). The creation of relationships between ideas in the new information and prior knowledge creates a greater number of retrieval paths that may be used for activating a particular chunk of knowledge (Anderson, 1983). Activation of a particular node within the network will increase the probability of activating a target node if the nodes within the network are highly interconnected. Therefore, connecting the target fact to some prior knowledge by creating an elaboration will produce greater retrieval because the likelihood of activating the corresponding network has increased, and thus the likelihood of retrieving the target information is increased.

This line of research suggests that it is the **act** of generating the elaboration rather than the elaboration itself that makes the facts more memorable, and may be an instance of the generation effect (Slamecka & Graf, 1978).

This claim is supported by two pieces of evidence. First, students who generate an elaboration tend to remember the target fact more than students who merely read a phrase that clarifies the target fact (Pressley et al., 1987; Wood, 1989). This means that the act of creating an elaboration makes the target information more memorable by integrating it with prior knowledge. Second, when students are required to generate their own elaboration, the clarity of the elaboration does not seem to be a factor. Students who generate elaborations which do not clarify the relationship stated in the target fact are as likely to remember the fact as are students who generate elaborations that do clarify the relationships contained in the target fact when the stimulus materials are prose-like rather than discrete, arbitrary sentences (Woloshyn et al., 1990; Wood, 1989; Pressley et al., 1988 experiments 3 and 4). The implication here is that students are likely to generate elaborations that are consistent with their own prior knowledge and suggests that the target information will be integrated with knowledge the learner already possesses.

The act of generating an elaboration involves two potentially different cognitive operations. Suppose the student were to read *The hungry man got into his car* and were asked *Why would that particular man do that?* Students could answer this question using two different cognitive operations - retrieval or inference. If the student possesses knowledge of hungry men and restaurants, and these two items of information have been linked, then the learner can retrieve the answer. A schema for hungry men already exists and one of the slots or items of information associated with the schema is going to a restaurant. The student already knows the answer.

However, a more likely operation is inference. The student activates or creates a mental model which is used to relate the objects in the target fact. Such a mental model might consist of a set of rules which, if activated, will connect the pieces of information (Holland, Holyoak, Nisbett, & Thagard, 1986). For example, the learner could construct the rules:

> If hungry, then need food.
> If need food, then need to eat.
> If need to eat, then need to go to restaurant.
> If need to go to restaurant, then need to drive car.
> If need to drive car, then need to get in car.

Using such a set of rules, it is easy to see how the learner can relate the attribute of hungry to the act of getting into the car.

Although the generation hypothesis has been accepted as the explanation for elaboration (Mayer, 1983), recent evidence suggests that a modified generation hypothesis is needed based on epistemological considerations in generating elaborations which may influence memory for a fact. Not only must learners integrate new ideas with prior knowledge by creating assemblies, but the outcome of that operation is important. Wood (1989, experiment 2) had students in one group generate elaborations to *why* questions about a set of animal facts. The elaborations were subsequently coded as explanatory, not explanatory, or no response. An explanatory elaboration was one which clarified the relationship between the animal and its attribute, and was further scored as either correct or incorrect. Wood reported that of those students who provided explanatory elaborations, students who responded with correct explanatory elaborations were far more likely to remember the target fact than students who responded with incorrect explanatory elaborations. In other words, correct reasoning about the animal was far more likely to produce learning than incorrect reasoning, even though the incorrect reasoning clarified the relationship between the animal and its attribute.

In a recent study, Martin & Pressley (1991) report results that suggest a similar conclusion. In their study, students were divided into five treatment groups. Students in all groups read facts about Canadian provinces, such as *The first Canadian-based farm protest organization was formed in Manitoba.* One group was a reading control group. The remaining groups engaged in elaborative interrogation. However, the way in which students were to respond to the *why* question was altered for each of the four groups. Students in the first elaborative interrogation group were asked *Why does that make sense given what you know about that particular province?* Students in the second elaborative interrogation group were asked *Why does that make sense given what you know about other provinces?* Students in the third elaborative interrogation group were asked *Why is this unexpected given what you know about this province?* Students in the fourth elaborative interrogation group were asked *Why is this unexpected given what you know about the other provinces?* The results of the study showed differential effects on both recall and an associative memory task. Students in the first elaborative interrogation group were more likely to remember a fact than students in the other elaborative interrogation groups, and students in the fourth elaborative interrogation groups were least likely to remember the fact.

The results reported by Wood (1989) and Martin and Pressley (1991) suggest that the way in which a student relates the target fact to prior knowledge is important. The elaboration aims to clarify the relationship stated in the target fact. The results from Wood's study imply that if that relationship is not epistemologically correct the target fact is not likely to be remembered. The results from Martin & Pressley suggest that prior knowledge used to clarify the relationship is of importance in determining the probability that the fact is remembered. This finding is consistent with research using experimenter-provided elaborations which found that the explanatory power of the linking phrase influenced the memory for the fact (Stein & Bransford, 1979). In other words, the conclusion from these studies is that cognitive structures which tend to be epistemologically correct lead to better memory for facts.

Given that the cognitive structure which results from engaging in elaborative interrogation is an important consideration, the question to ask is why non-explanatory elaborations are as effective as correct, explanatory elaborations and more effective than incorrect, explanatory elaborations. The answer to this question is unclear. One hypothesis is that students generate non-explanatory elaborations because they are unable to generate explanatory elaborations. The production of a non-explanatory elaboration is to satisfy experimenter demand. The students are just trying to answer the question. However, they also resort to some other strategy, such as rehearsal, as the means for learning the target fact. So students are engaging in rehearsal, or some other strategy, instead of elaboration and are producing a non-explanatory response as a means for answering the question.

Elaborative Interrogation as Self-questioning

For learning to occur, the learner must actively engage in the cognitive processes of relating new ideas to each other, or relating new ideas to prior knowledge (Wittrock & Alesandrini, 1990; Wittrock, 1989; Wittrock, 1986). Self-questioning has the effect of promoting active cognition on the part of the learner (Wong, 1985). That is, self-questioning requires the learner to attend, organize, elaborate, and monitor (Weinstein & Mayer, 1986). Some questions are designed to have the learner attend and organize the information (Wong, 1979; Andre & Anderson, 1979) by asking them the main idea or to paraphrase the passage. This has the effect of getting learners to build relationships between ideas contained in the passage. Some questions require the learner to think of new examples of an idea (Andre & Anderson, 1979) or to make inferences about the idea in the passage (Wood, 1989; Pressley et al, 1988; Wong & Sawatsky, 1984; Stein & Bransford, 1979). This requires the learner to elaborate and has the effect of connecting the ideas in the passage to prior knowledge. Other questions require the learner to monitor their comprehension (Wong and Jones, 1982). Such questions require the learners to use meta-cognitive skills.

Elaborative interrogation can be thought of as a form of self-questioning. In self-questioning, the reader spontaneously generates questions about the information the student is reading, or is trained to generate questions about what he has just read. Elaborative interrogation involves teaching students to generate answers to *why* questions, and getting students to ask *why* questions spontaneously.

Self-questioning as a strategy training technique, is useful if students are not already engaging in that strategy. Wong (1979) taught 15 learning disabled students and 15 normally achieving students a self-questioning strategy. Each student listened to a story being read aloud by the experimenter while they followed the print visually. Prior to each paragraph, the experimenter read aloud a question about that paragraph. Compared to a no-questions group, results showed learning disabled students who were given questions improved in performance. However, normally achieving students who received questions did not improve their performance compared to normal achieving students in the no-questions group. This, argues Wong (1979), demonstrates that asking learning disabled students to answer questions requires them to engage in some form cognitive activity and that normally achieving students already engage in such cognitive activity and may not benefit from training.

Results of previous studies (Wong, 1979; Pressley et al. ,1988, 1987; Wong & Sawatsky, 1984) suggest that normally achieving readers engage in cognitive activity that has the effect of helping them organize and assemble relationships between the new ideas. This is supported by the fact that self-questioning training has no effect for normally achieving students *when the questions require them to organize the ideas*. These readers are already engaging in some form of assembly operation that enables them to relate ideas in the text to each other. However, when students must answer questions that require operations involving assembling relationships between ideas in the text and prior knowledge (elaboration), the self-questioning training has an effect (Andre & Anderson, 1979). Thus, it may be the case that normal achieving students do not spontaneously connect the ideas contained in the passage with prior knowledge. Asking *why* questions requires them to build relationships they would not otherwise build. They engage in additional cognitive activity to produce greater gains in learning. In other words, we can conclude that learners spontaneously engage in strategies to assemble links between ideas within text, but do not spontaneously engage in strategies to assemble links between ideas in the text and prior knowledge.

Elaborative Interrogation and Prose Passages

More recently, researchers examining elaborative interrogation have begun examining the potential effects of elaborative interrogation with materials that resemble expository prose. Wood (1989, experiment 2) performed a study to examine the effects of elaborative interrogation when the facts were constructed to resemble a prose passage. Her study used a set of 54 sentences about animals. This set consisted of 6 sentences about 9 different animals. For example, students read the fact *The grey seal lives with a group of other grey seals.* Students in the elaborative interrogation group were required to answer the question *Why does that animal do that?* while students in the reading control group only read the fact. Results on the memory test showed the superior performance of the elaborative interrogation group.

Another study (Woloshyn et al., 1990) used materials that contained statements about Canadian universities. Each set of facts about a single university contained six statements about unique features of that university, such as *The campus at McMaster University is full of wild life.* In the first experiment (Woloshyn et al., 1990 Experiment 1) the students read each fact separately from the other facts. In experiment 2 (Woloshyn et al., 1990 Experiment 2) one experimental condition had the facts for each university form a paragraph and the students read the facts in paragraph format. Results showed that reading the facts in paragraph format produced greater recall than reading the sentences in sentence format. As well, students in the elaborative interrogation group exhibited superior performance compared to a reading control group on memory tests.

Although these studies have shown elaborative interrogation to be superior to reading control groups in performance on memory tests, an important consideration remains. These studies used material that was not highly organized; the facts were still unconnected. Early studies (Pressley et al., 1987; Wong & Sawatsky, 1984; Stein et al., 1982) used material such as *The ugly man bought some plastic* and *The hungry man got into the car.* These two sentences are unconnected and arbitrary and are not representative of a normal reading task. Similarly, the study by Pressley et al. (1988, experiment 3,4) used facts that were about Canada or gender differences, but were still unconnected. Any of the facts could be replaced by another on the same topic. The sentences lacked cohesion. The study by Wood (1989, experiment 2) used facts about animals. Such facts could be related to each other in more than a simple hierarchical fashion (that is, just being about that particular animal). However, examination of the actual facts used in the materials shows that the facts lack any significant organization beyond being about the same animal. Similarly, the study by Woloshyn et al. (1990) also used facts that possessed simple hierarchical organization. For example, two facts about McGill University were *The land on which McGill University stands was donated by a fur trader* and *The university's first faculty was a medical faculty.* Other than being about McGill University, these two facts are not explicitly connected and can be organized in a simple hierarchical fashion, as shown in figure 2.1.

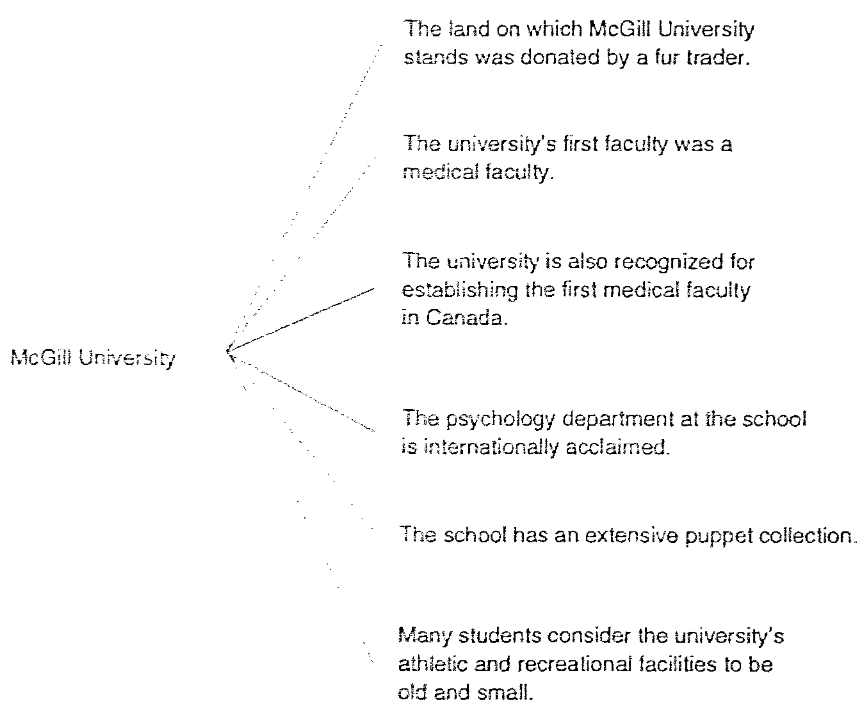

Figure 2.1. The hierarchical arrangement of facts used in Woloshyn et al. (1990).

This is an important consideration because most academic learning involves prose that consists of facts that are richly related to other facts. There is an organization inherent in the facts to be learned which goes beyond a simple 1-level hierarchy. Often a single paragraph will contain a set of facts that are interconnected - that is, they are about a common sub-topic within the paragraph or are extensions of each other. The ideas in the paragraph can be described using text structures (Cook & Mayer, 1988; Winne, Seifert, & Butler, 1991). A single fact is part of a larger body of ideas constituting a knowledge domain.

For certain domains, such as science, the organization of the facts within the passage can become quite complex. Facts within science are illustrative of principles. For example, suppose a passage about the snowshoe hare contained the following facts:

> During the winter time, the snowshoe hare has a coat of fur that is white.
> The ears of the snowshoe hare are large and upright.
> Female snowshoe hares give birth four times each year.
> Each litter may contain as many as nine young.

In this example, each fact illustrates a principle of adaptation. The fact that the snowshoe hare turns white in winter illustrates the principle of protective camouflage. The fact that the snowshoe hare gives birth four times each year illustrates the principle of reproductive survival.

This example contains several facts that can be arranged in two ways. First, the description could be seen as a list of four arbitrary facts that are about a particular topic, the snowshoe hare. Each fact is treated as being isolated from the others and is related only to the broader topic. The information, as a whole, creates one large chunk of knowledge about the snowshoe hare organized in a single level hierarchy, similar to that depicted in figure 2.1. In this regard the passage resembles earlier studies on elaborative interrogation.

A second possible arrangement is to view the facts in context with other facts and belonging to some domain of knowledge. Each of the facts could represent a main idea of a paragraph, or be a detail within a paragraph. There are smaller chunks within a larger chunk and a schema can be based upon the characteristics of the animal. Additionally, each fact is illustrative of a principle of adaptation. For example, the fact stating the coat is white during winter illustrates the principle of protective camouflage. In such a situation, the learner has opportunity to build associations between the facts about the animals and the principles of adaptation. Graphically, such associations are represented in figure 2.2.

Suppose a core set of facts, such as the four facts about the snowshoe hare listed previously, was selected such that each fact was the main idea of a paragraph. One such paragraph might be:

> During the winter the coat of the snowshoe hare is white in colour. This change in colour is the result of changes in daylight and temperature. As the weather turns colder and the days become shorter, the outer hairs of the summer coat are shed and hairs for the winter coat grow in their place. The summer fur is gradually replaced by winter fur.

Each sentence in the paragraph supports and expands the main idea. Further, each of the main ideas is illustrative of a scientific principle. Clearly, such an arrangement of facts is characteristic of a typical expository reading passage, and represents a complex and rich domain. Given such conditions, some interesting questions arise.

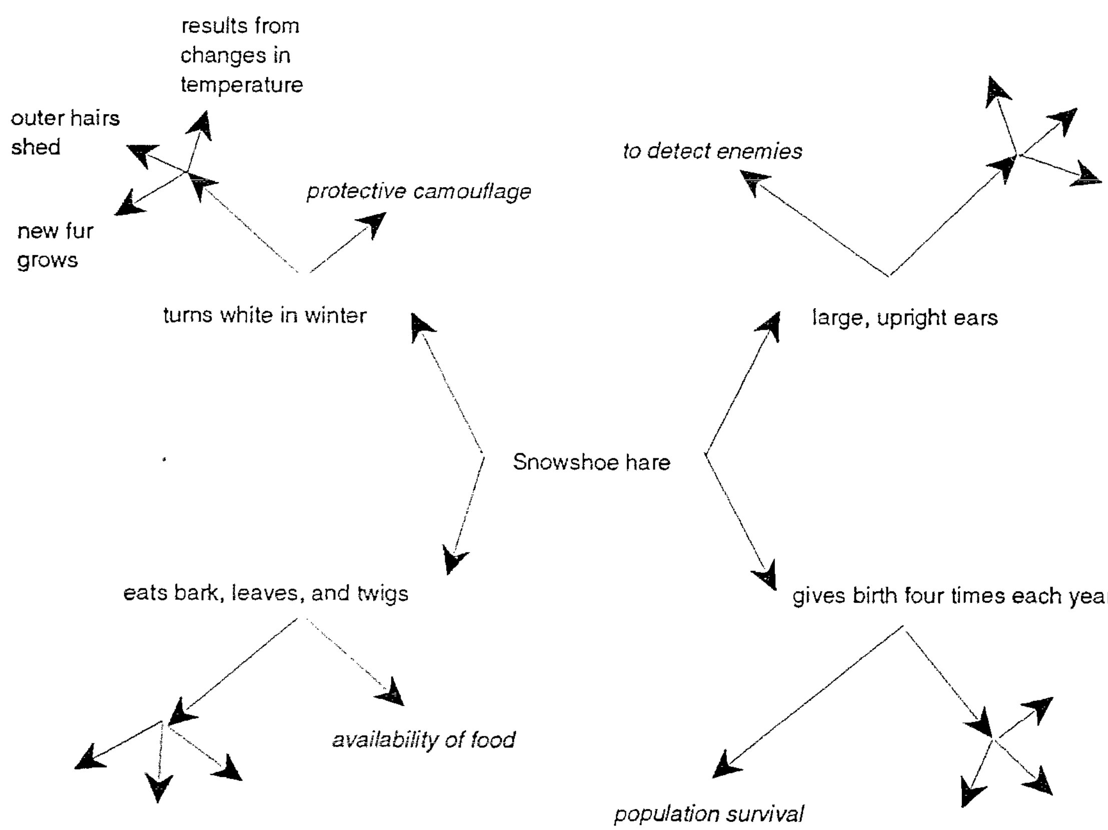

Figure 2.2. A more complex arrangement of facts, with multiple associations.

In learning the target fact students must read the paragraph and locate the main idea. Given that the target fact is embellished by supporting details, is elaborative interrogation a useful way of enhancing learning? In other words, can elaborative interrogation contribute to learning from meaningful prose above and beyond reading and comprehending the passage. Alternatively, if an additional sentence which links the target fact to the prior knowledge is provided to the learners, does that linking sentence contribute to learning beyond that of just reading the passage and comprehending it? Is generating an elaboration more effective than being provided with one?

This intent of this study is to replicate and extend the findings of previous elaborative interrogation research in a context where the target facts that are located within a rich, complex domain. As a replication, it is intended to determine whether certain trends found in previous research still exist. It examines the effectiveness of elaborative interrogation for memory for facts. It also examines whether memory for facts is dependent upon the explanatory nature of the elaboration. However, one other significant feature has been added. This study will examine the relationship between the elaboration and prior knowledge more closely than has been done in prior studies. Specifically, an attempt is made to determine if elaborative interrogation does help learners link new information to prior knowledge, whether such links are necessary for learning, and the nature of the links that would otherwise be required.

Specific predictions are made on the basis of past research:

1) Elaborative interrogation is effective in the context of a rich domain of facts, but its effectiveness is diminished because of the other cognitive operations that may arise during the course of reading a paragraph and comprehending.
2) Explanatory elaborations are not more effective in aiding memory than non-explanatory ones.
3) Elaborative interrogation provokes learners to relate new information to prior knowledge by engaging in an assembly operation, and is a necessary condition for learning.

Chapter 3: Methodology

Subjects

Participants in this study were 114 grade six and seven students from six classes in two school districts of British Columbia. There were 59 males and 55 females. Although the initial pool was larger, several students had to be dropped from the data analysis because of absence during either of the two sessions, or failure to complete the assigned tasks. The remaining students were randomly assigned to one of four groups. The study was conducted over a two day period using intact classes with random assignment occurring within classrooms.

Materials

The materials were two reading booklets. The first booklet described five general rules of adaptation (Morris, 1990) that explain the characteristics and behaviours of animals, such as *Animals have special ways of detecting their enemies.* The booklet was eight pages long. The first page introduced the rules of adaptation, stating that scientists have discovered reasons for the way animals look and behave. The next three pages presented the rules of adaptation. Two rules were presented on each page. Each rule was printed in italics and was followed by an explanation of the rule. The explanation was followed by a paragraph presenting examples The examples were not related to the animals described in booklet 2.

The remaining two pages were blank so students could write study notes. One of these was pink and was used for writing notes as they studied the rules. The instructions were provided on the first page of the booklet and stated:

> **Look carefully at each rule** which has been highlighted in italics for you. **Read the example**. In your own words, **write the rule** in the space provide on the pink sheet called study notes.

The second page was white and was used for self-testing. Instructions were written at the top and read as follows:

Without looking back, write down as many of the rules as you can remember in the space below. When you are done, go back and look for any you may have forgotten. Write them in the space below.

The numbers one to five were written in the margins with considerable space between each number. Students tried to recall as many of the rules as they could and write their responses next to each number. They were allowed to review any they may have forgotten to provide additional studying. The objective of session 1 was to maximize student's knowledge of the rules of adaptation. The reading passage is presented in Appendix A.

The second booklet consisted of three 6-paragraph prose passages about three different animals. These passages were printed on 8.5 x 11 paper using landscape orientation. The page was divided vertically into halves. Two paragraphs were printed on the left half of each page. The right half of each page was reserved for students to carry out tasks that corresponded to the treatment condition to which they were assigned. The first page presented instructions, which are described fully in the treatments sections.

The first paragraph was an introductory paragraph about the animal. The remaining paragraphs described some characteristics and behaviours of that animal. The first sentence of the each paragraph was the main idea and was the target fact to be elaborated. This sentence described a characteristic or behaviour of the animal and was an example of one of five rules of adaptation. For example, one target sentence read *During winter, the coat of the snowshoe hare is white in colour.* This fact is an example of the rules of protective camouflage. In total, five rules of adaptation were used and each was used once for each animal.

The remaining sentences in the paragraphs expanded the idea of the target fact without providing any additional information about the relationship between the target fact and the scientific principle. For example, the additional sentences in the paragraph explaining that snowshoe hares turn white in winter described the physical cause of the change in colour. None of the additional sentences made reference to the principle of adaptation. One such sentence states, *This change in colour is triggered by changes in temperature and daylight.* The complete reading passages are found in Appendix B.

Treatment Conditions

Students were assigned to one of four groups based on the booklet they read. Students in each group read the booklet describing the characteristics and behaviors of three specific animals and performed a task while reading which differed across groups. The booklets presented the same factual material in three of the four groups. The remaining group read the same factual material as the other groups, but read one additional sentence in each paragraph.

In the first group, the *underline only group*, students were instructed to read each paragraph carefully. The instructions to this group read:

1. Read the following descriptions of three common animals.
2. Read each paragraph carefully.
3. Some paragraphs have a sentence beside them. This sentence tells you to underline the most important idea in the paragraph. When you see this sentence, underline the most important idea in the paragraph. Underlining will help you learn the main idea.

Beside each paragraph was a prompt which stated *Underline the most important idea in this paragraph.* An example of a paragraph read by these students is:

> During the winter the coat of the snowshoe hare is white in colour. This change in colour is the result of changes in daylight and temperature. As the weather turns colder and the days become shorter, the outer hairs of the summer coat are shed and hairs for the winter coat grow in their place. The summer fur is gradually replaced by winter fur.

The second group, called the *underline with elaboration group*, was also required to underline the most important idea in each paragraph. However, the paragraphs that these students contained a single sentence that linked the target fact to the appropriate principle of adaptation. The instructions to students in this group were identical to those of the underline only group as was the prompt to underline.

An example of a paragraph read by students in the underline elaboration group is:

> During the winter the coat of the snowshoe hare is white in colour. The colour provides protection from enemies by making them hard to see. This change in colour is the result of changes in daylight and temperature. As the weather turns colder and

the days become shorter, the outer hairs of the summer coat are shed and hairs for the winter coat grow in their place. The summer fur is gradually replaced by winter fur.

The third group, the *generate elaboration group*, read the same base passage as the underline only group. Students in this group were required to read each paragraph. After reading a paragraph, students were required to answer a *why* question written beside the paragraph. The instructions provided to students read:

1. Read the following descriptions of three common animals.
2. Read each paragraph carefully.
3. Beside most paragraphs is a question. After reading the paragraph, write your answer to the question in the space below the question.

For example, students read the paragraph which had the target fact *During the winter coat of the snowshoe hare is white in colour.* The corresponding *why* question was *Why would the snowshoe hare need to be white in colour during winter?*

The fourth group, the *elaborate with study sheet group*, was identical to the generate elaboration group with one notable exception. The pink study sheets from session one were returned to the students and the students were allowed to refer to these for assistance in answering the *why* questions. Instructions to the students were:

1. Read the following descriptions of three common animals.
2. Read each paragraph carefully.
3. Beside most paragraphs is a question. After reading the paragraph, write your answer to the question in the space below the question. Use your study notes (on the pink sheet) to help you with your answers.

Measures

The measures consisted of a variety of achievement and motivation measures. At pretest, students completed a demographic survey, rating scales, and an achievement measure. At posttest, they completed rating scales assessing motivation, and a variety of tasks assessing achievement. The measures are presented in Appendix C.

At pretest, students completed a short set of survey questions asking age, gender, grade, and current level of reading achievement. This was followed by a set of seven point rating scales asking students to rate their interest in animals and science, as well as their knowledge of six specific animals (the three target animals and three distractors).

The pretest achievement measure consisted of an associative memory task which is shown in Figure 3.1. Students were presented with a single page of paper, printed landscape style. In the center of the page were the names of the three target animals and two distractor animals. Around the edge of the paper were printed twenty-two phrases describing characteristics and behaviours of the animals. The 15 target facts from the second reading passage were represented. Five of the phrases were details that were subordinate to the target facts in the passage. The remaining two phrases were from the introductory paragraphs of two of the animals and were used as examples of how to do the task.

The instructions were printed on a separate page and informed students of their task:

> The following page has a number of characteristics and behaviours of animals on it. In the center of the page are five animals. Read each characteristic and behaviour. Decide which animal it belongs to and draw a line from the characteristic to the animal. For example, the snowshoe hare is a common forest animal, so a line has been drawn from *common forest animal* to *snowshoe hare.* Similarly, the American Woodcock is highly prized by hunters, so a line has been drawn from *highly prized by hunters* to *American Woodcock.*
>
> **Match the characteristic to the animal.** *Note: a characteristic might be true of more than one animal or it might not be true of any of the animals.*

To illustrate the task, a line had been drawn from *snowshoe hare* to *common forest animal* and from *American Woodcock* to *highly prized by hunters* on the matching task.

The posttests consisted of a motivation rating scale and several different achievement measures. The motivation rating scale consisted of five items utilizing seven point rating scales and assessed students reactions towards the tasks they had just completed with regards to interest, difficulty, efficacy, importance, and effort. This scale was administered after reading the first booklet, and again after reading the second booklet prior to the achievement measures.

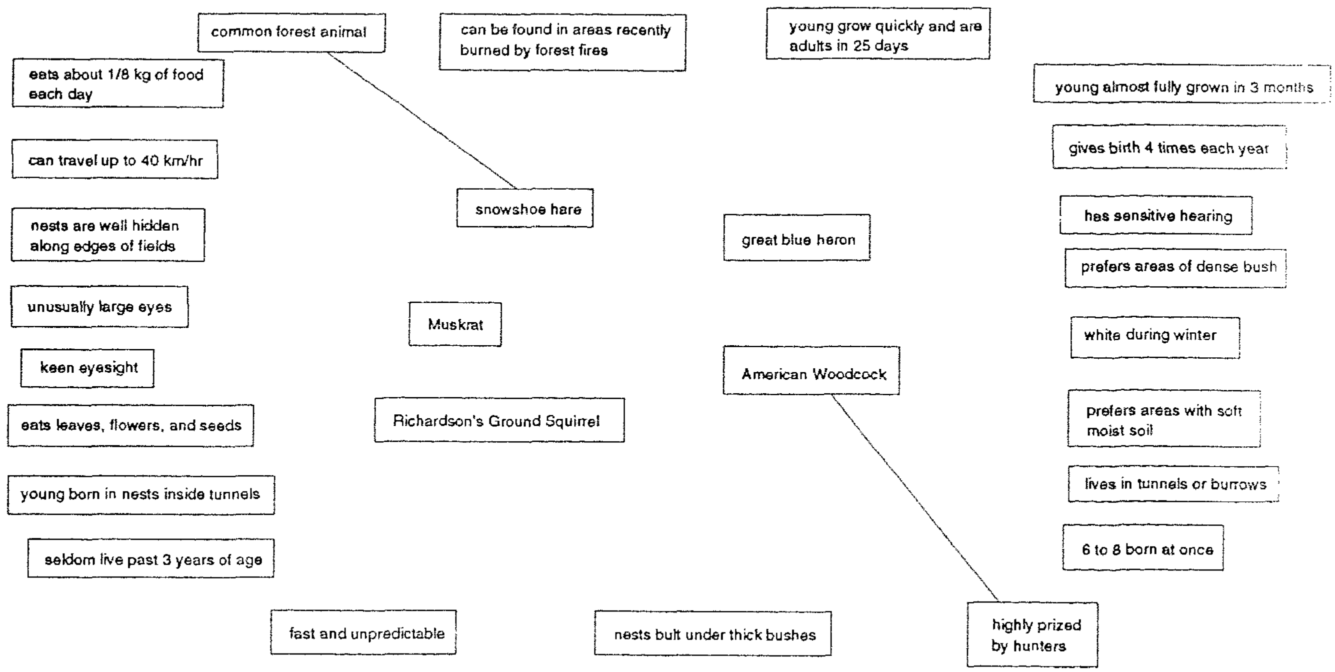

Figure 3.1. Associative memory task used at pretest and post-test.

The posttest achievement measures consisted of three tasks: a free recall task, a series of short answer questions, and a test of associative memory. The free recall task consisted of a single instruction to students and was designed to elicit the structure they had placed upon the information they had read about. The instructions read:

> Suppose you have just been asked to write an article for a wildlife magazine. The topic of this article happens to be the animals you have just read about, and the scientific reasons for their characteristics and behaviours. Based on the information you have just read in your two sessions, write the story you would give to the magazine in the space below. Use the back of the page if you need extra space.

The second task consisted of 14 short-answer questions constituting three subscales. The first subscale, the *assembly subscale*, consisted of nine questions that examined whether students had made links between the target fact and a principle of adaptation. For example, students had read the fact *During winter the snowshoe hare is white in colour.* This fact relates the attribute to the animal. In one treatment group, while reading the text, students answered a *why* question such as *Why would the snowshoe hare need to turn white in winter?* Answering this question requires the student to build a connection between the characteristic of the animal and the principle of adaptation. The short answer question on the posttest asked *How does the snowshoe hare protect itself from enemies?* Answering this question requires the student to activate the connection between the principle of adaptation and the characteristic of the animal.

The second subscale on the short-answer test, the *details subscale*, consisted of three items which assessed memory for details. Students' recollection of information presented in the text that was subordinate to the target ideas was assessed. An example of one of the questions asked is, *How fast can the American Woodcock fly?*

The third subscale, the *problem-solving subscale*, presented two questions to test students' problem-solving abilities. These consisted of two questions requiring students to make a prediction about the characteristics and behaviours of the animals in situations that were not presented in the passage. One question asked students how the snowshoe hare might protect itself in summer, and the second asked how the American Woodcock might get food to eat in the winter. The final posttest achievement measure was identical to the measure of associative memory administered as the pretest.

Scoring

The pretest interest and knowledge rating scales were scored on a scale from 1 to 7. A value of 1 meant that students had no interest in science or animals while a value of 7 indicated they had considerable interest. On the self-rating of knowledge a value of 1 indicated they felt they had no knowledge of the animal while a rating of 7 meant they felt they had considerable knowledge of the animal.

The pretest and posttest measures of associative memory were scored by counting the number of lines correctly linking the characteristic or behaviour and the correct animal. A score of 1 was provided for a correct response and 0 for an incorrect match or missing line. The maximum possible for target ideas was 15 and for details was five. The target ideas and details were combined for a total test score with a maximum of 20.

The motivation scales were scored as rating scales from 1 to 7. Each item was analyzed separately, not as a combined scale. Hence the maximum possible score for each motivational construct was 7. On each of the scales, a value of 1 meant the lowest possible value for the motivation construct. That is, a value of 1 meant the task was not very interesting, not very difficult, low efficacy, low importance for learning, and low effort. Conversely, a value of 7 meant high interest, very difficult, high efficacy, great importance, and high effort.

The short answer questions comprising the *assembly* subscale and the *problem-solving* subscale were scored by categorizing the responses of the students. Four categories of responses were created: the correct and intended response, incorrect but plausible response, incorrect and indeterminant responses, and no response. A correct and intended response meant the student answered the question correctly using both the knowledge of the principle and knowledge of the characteristic of the animal. A plausible response meant the student utilized a principle other than the correct one in creating their response. Although their answer was incorrect, it clearly reflected reasoning based upon one of the other principles presented in the first passage. A response was coded as indeterminant if it was vague, incorrect, and not related to any of the rules of adaptation. A response in this category was incomplete and lacked any explanation related to the principles of adaptation. Examples are provided in Table 3.1 and Appendix C. The questions comprising the details subscale were coded as correct (1) or incorrect (0). Inter-rater agreement was 86% on categorizing student responses.

Table 3.1. Categories and examples of responses to assembly subscale questions.

Question: How does the snowshoe hare protect itself from enemies?

Correct and intended response	Camouflage. Change colour. Blend in with surroundings. Turn white.
Plausible response	Detect enemy. Long ears & good eyesight. Hide in bushes.
Indeterminant response	So it won't get killed. Hide from enemy. Hide.

In a manner similar to coding and scoring responses to the short answer questions, students' responses to the *why* questions were coded and scored. The categories used were identical to those for scoring the short answer questions, as were the criteria for categorization. Inter-rater agreement was 93% on the short answer questions. Table 3.2 presents some examples of responses in each of the categories.

Students who were in the underline only group and the underline with elaboration group had their performance on the underlining task scored. Underlining was scored by recording which information was underlined. This produced three categories for students in the underline only group: underlined information in target sentence, underline information other than the target fact, or did not underline anything. If students underlined information in the target sentence plus other information it was scored as underlining target information.

Table 3.2. Categories and examples of generated elaborations.

Question: Why would American Woodcock chicks need to grow fast?	
Correct and intended response	Population survival. Become adults and breed. Have more chicks. Produce more & survive.
Plausible response	Protect themselves. Fend for themselves. Protection from enemies.
Indeterminant response	Natural protection. Huge appetite. Short life.

Students in the underline with elaboration group had their performance coded into five categories: underline target information, underline elaboration, underline both target and elaboration, underline information other than the target fact or elaboration, or did not underline anything. As with the underline only group, students who underlined the target sentence and other information were counted as underlining the target information;

students who underlined both the elaboration and other information were counted as having underlined the elaboration.

The data from the free recall task were not scored and analyzed in this study. Indications from students suggest that the students did not respond to this task appropriately. There was ambiguity in the task such that they could not follow the instructions properly. During the study several students inquired whether they should write about one animal or all three. During the interview, students indicated that they were not sure whether they should write about one animal or all three. Examination of the recall protocols indicated that many students attempted to write a story rather than an expository text. In light of these complications, free recall data was not scored or analyzed.

Students' reading ability was measured by obtaining final report card grades from classroom teachers. Grades were reported as letters and converted to a numerical value using the following conversion:

A	8	C+	4
B+	7	C	3
B	6	C-	2
B-	5	D	1

Procedures

The study was divided into two sessions. The first session provided identical information and tasks to all students. The purpose of this session was to provide students with knowledge they might need in the second session. Students were randomly assigned to treatment conditions in the second session and the experimental tasks were conducted during this session. Six students were interviewed during a third session as a follow-up to the tasks they had responded to the previous day. Table 3.3 illustrates the groups and the tasks performed by each.

Table 3.3. Experimental groups and procedures.

Underline only group	Underline with elaboration group	Generate elaboration group	Elaboration with study sheet group
Session 1			
Pretest	Pretest	Pretest	Pretest
Read Booklet 1	Read Booklet 1	Read Booklet 1	Read Booklet 1
First posttest	First posttest	First posttest	First posttest
Session 2			
Read Booklet 2	Read modified Booklet 2	Read Booklet 2	Read Booklet 2
Underline main idea	Underline main idea	Answer why question	Answer why question
Posttest	Posttest	Posttest	Posttest
Session 3			
Interview		Interview	

The first session consisted of three parts: the pretest, the first reading booklet, and the posttest motivation measure. The session began with students responding to the pretest measures. They completed the short survey items followed by the interest and knowledge rating scales. The last pretest measure was the associative memory task.

After completing the pretest, students the read the first booklet. The instructions provided to the students required them to read each rule, the explanation, and the examples. Then they were to write the rule on the pink study sheet in their own words.

After they had studied all the rules, they were required to recall each of the rules, without looking back. When they had recalled as many rules as they could, then they were allowed to go back and reread any rules they may have forgotten.

The second session consisted of two parts. The first part involved reading the second booklet describing the characteristics and behaviours of three animals. During the reading students engaged in their various experimental tasks. The second part of the session consisted of posttest measures including the motivation rating scale and the achievement measures.

When students had completed reading the booklet, they then completed the posttest measures. The first was the five item motivation measure assessing their motivational reaction to the reading task. This was followed by the free recall task, the short answer questions, and finally the associative memory measure.

The third session was the interview session. Six students, three from the underline only group and three from the generate elaboration group, were randomly chosen by the teachers to participate in an interview. Students were interviewed in two groups of three and the interviews lasted about 15 minutes each. The interviews probed students reactions to the tasks, their understanding of task requirements, and self-questioning as a strategy.

Chapter 4: Results

The data analysis was conducted in three phases. The first phase examined the measures to ensure that they functioned in an appropriate manner. The second phase explored between-groups comparisons to determine the effect of elaborative interrogation on the various outcome measures. The third phase analyzed conditional probabilities to examine the manner in which elaborative interrogation influenced learning.

The Measures

Five constructs related to motivation were measured using single item 7-point scales for each construct (interest, difficulty, efficacy, importance, effort). Descriptive statistics (Table 4.1) showed that the students found reading the passage moderately interesting, fairly easy, thought they learned about the animals fairly well, thought it was somewhat important to learn, and tried reasonably hard. Correlations (Table 4.2) showed that those students who found it interesting also thought they did well (r = .42), thought it important to learn (r = .62), and exerted effort (r = .43). The easier they thought the task was, the better they thought they did (r = .33) and the better they thought they did, the more they thought it important to learn (r = .30). Those students who thought it important to learn also reporting trying the hardest (r = .53).

Table 4.1. Descriptive statistics for motivation during second session and p levels from univariate ANOVAs.

	Interest	Difficulty	Efficacy	Importance	Effort
Underline only (n=28)	4.7 (1.3)	2.2 (1.4)	4.0 (1.2)	3.8 (1.6)	4.0 (1.6)
Underline with elaboration (n=30)	4.7 (1.6)	2.5 (1.4)	4.4 (1.4)	4.1 (1.7)	4.4 (1.5)
Generate elaboration (n=27)	3.9 (2.1)	2.8 (1.8)	4.5 (1.6)	3.0 (1.9)	4.3 (2.1)
Elaborate with study sheet (n=29)	4.7 (1.8)	2.3 (1.4)	4.8 (1.4)	4.3 (1.4)	4.5 (2.1)
Total Sample	4.5	2.5	4.4	3.8	4.3
	p=.19	p=.41	p=.30	p=.04	p=.68

Table 4.2. Correlations among motivation constructs and reading level (session 2).

	Grade	Interest	Difficulty	Efficacy	Importance	Effort
Grade	1.0					
Interest	-.04	1.0				
Difficulty	-.01	.04	1.0			
Efficacy	-.01	.42**	-.33*	1.0		
Importance	-.03	.62**	.01	.3*	1.0	
Effort	-.08	.43**	.02	.17	.53**	1.0

* p<.01 ** p<.001

A MANOVA yielded a statistically detectable difference between groups on these five constructs ($\Lambda = .63$, $p<.03$). Subsequent univariate analyses showed the only difference to be on the importance of learning variable. Examination of the group means in table 4.1 shows that the generate elaboration group had a lower mean on this item than the other groups. However, the impact of this difference on subsequent performance can be downplayed for two reasons. First, the generate elaboration group did outperform the underline only group on the posttest measure of associative memory at a statistically detectable level[1]. Hence whatever effect the low importance scores may have had on the performance of students in the generate elaboration group, it was not enough to mask effects (although it may have weakened them).

The second reason for downplaying the group differences on the importance construct is the zero correlation between importance and posttest achievement ($r = .07$). Variation in students' scores on the importance variable did not influence subsequent performance on the posttest. (see Table 4.3).

Table 4.3. Correlations of motivation with achievement.

Achievement	Interest	Difficulty	Efficacy	Importance	Effort
Associative memory	.19	-.01	.19	.07	-.03
Link to prior knowledge	.10	-.07	.25	-.04	-.10
Memory for details	.23	-.08	-.03	.15	.12

1 These differences will be discussed further in a later section.

Table 4.4. Performance on experimental tasks by group.

	Underline target sentence	Underline elaboration or both target & elab.	Underline other sentence	Did not underline
Underline only group	66%	---	34%	.3%
Underline with elaboration group	47%	24%	27%	1%

	Correct Response	Plausible Response	Indeterminant Response	No Response
Generate elaborations	64%	10%	21%	5%
Elaborations with study sheet	66%	9%	21%	4%

Given that students were reasonably motivated to perform their various tasks, did they adequately perform their tasks? Frequency tables (Table 4.4) show that students engaged in their respective tasks 97% of the time. Out of 1710 possible instances of underlining or question answering, only 45 no responses were recorded. In other words, students made a data trace for almost every paragraph.

Students in the underline only group correctly identified the target sentence as the most important idea 66% of the time. Students in the underline with elaboration group underlined the target sentence, the elaboration, or both, 71% of the time. Students in the elaboration groups were able to provide an answer to the *why* question for 95% of the paragraphs, able to provide a correct or plausible answer at least 74% of the time. Students were able to generate some sort of answer to the questions, but not necessarily the correct one.

An item analysis was conducted on the short answer questions and associative memory matching task. This consisted of estimates of internal consistency and item difficulty. Internal consistency coefficients were .44, .30, and .17 for the assembly, details, and problem-solving subscales respectively. The low internal consistency of the problem-solving scale suggests that the two items are not representing the same bit of knowledge. Hence, questions 13 and 14 will not be combined to form a subscale. The item difficulty levels showed the lowest item difficulty was .2 while the highest was .84. Item difficulties are shown in Table 4.5 and are computed based on a score of 1 for a correct response and 0 for any other response.

Table 4.5. Item difficulties for short answer questions.

q1	q2	q3	q4	q5	q6	q7	q8	q9	q10	q11	q12	q13	q14
.59	.84	.43	.49	.25	.41	.20	.64	.20	.76	.83	.64	.26	.59

While examination of the questions themselves may lead to the impression that the answers to the questions were obvious, the results showed that students did not find the answers that obvious. The questions were challenging to the students, yet were not beyond them. An alternative way of looking at the questions is to inspect the proportion of students who could not generate any answer to the questions, which is reported in Table 4.6. The minimum proportion of people to not generate any answer to a question was .05 and the maximum was .36. It seems that most students were able to write something in response to each question. The questions may have challenged them, but they did not find it impossible to generate an answer. This is an important consideration because it indicates that students could create some sort of relationship between the animal and the principle.

Table 4.6 Proportion of people not able to provide any answer to the short answer questions.

q1	q2	q3	q4	q5	q6	q7	q8	q9	q10	q11	q12	q13	q14
.08	.05	.12	.13	.19	.19	.23	.14	.18	.24	.17	.36	.18	.11

The effectiveness of the associative memory task as a measure of learning can be assessed on the basis of four kinds of evidence. First, if we assume that students know nothing about the three animals before reading the passage and they learn something about animals after reading the passage, then there should be a substantial increase in posttest scores over pretest scores. Results showed a mean pretest score of 2.9 and a mean posttest score of 12.0 ($t = 21.9$, $p<.001$). In other words, presuming that students would learn something from reading the passages, the results on the associative memory test indicates they did. Whereas students could recognize only three facts as correct before reading the passages, they could recognize 12 facts after reading the passages.

Second, two of the short answer questions assessed recall of a detail with the same facts appearing on the recognition test. For the first detail, a χ^2 test of whether or not the students recalled the detail, and whether or not they could correctly recognize it yielded a statistically detectable effect ($\chi^2 = 21.1$, $p<.01$, $\phi = .45$). In other words, if the students recalled that the Richardson's Ground Squirrel gives birth to 6 -8 young, they also recognized that fact on the posttest (Table 4.7).

The second short answer question was also contrasted with its counterpart on the recognition test. The χ^2 test was also statistically detectable ($\chi^2 = 26.9$, $p<.001$, $\phi = .52$). It is important to note that the assumption of minimum expected cell frequency was not met in this test (minimum expected frequency = 3.5). Yet, the distribution of frequencies (Table 4.7) is strong enough to reassure us that recall of details and recognition of details on the test was similar.

Third, since the grand mean of the associative memory posttest is 12.0 or 60%, the test can be considered of moderate difficulty. There are neither floor nor ceiling effects and the scores are normally distributed around the middle of the scale. Cronbach's α was .83, suggesting good internal consistency. Psychometrically, the data are well behaved.

Fourth, all of the alternatives presented on the matching task were paraphrases of ideas presented in the original article. To correctly answer a question, students had to comprehend the original idea, and had to interpret the attributes presented on the matching task to decide to which animal it belonged to. Consequently, this matching task should be a reasonably good indicator of comprehension (Anderson, 1972).

Table 4.7. Frequency distribution of recognition and recall on memory for detail questions.

First detail question		
	No recognition	Recognition
Incorrect recall	29	12
Recall	18	55
Second detail question		
	No recognition	Recognition
Incorrect recall	12	7
Recall	9	86

Between Group Contrasts

The between groups contrasts were conducted using dummy coded regression analyses. The dummy vectors formed a set of a priori contrasts in which the three elaboration groups were contrasted to the underline only group. All dummy vectors were entered simultaneously into the regression equation using a forced entry approach. The alpha level for each a priori contrast was set at .05 (Kirk 1968, p73, 78). The first analysis conducted was a between groups contrast of scores on the posttest associative memory measure. Results showed a statistically detectable difference between students in the generate elaboration group and the underline only group ($p<.05$) suggesting that students who generate answers to *why* questions learn more. Additionally, there are no statistically detectable differences between students in the elaborate with study sheet group and the underline only group, or between students in the underline and elaborate group and the underline only group. In other words, having access to information needed for elaboration while reading, or being provided with the elaborative material does not enhance learning. Also notice though, the differences in the number of items correctly recognized is small (Table 4.8). The group that generated their own elaboration recognized 3 more facts than the group that only underlined, an effect size of .67. Furthermore, although the differences between the other two experimental groups and the underline group are not statistically detectable, the effect sizes are moderately small (d = .32). Reading the elaboration, and utilizing the study sheets had marginal influence on learning. The effect sizes for these two groups was small (.32) but that effect was not statistically detectable.

Table 4.8. Between group contrasts on the associative memory task.

	Underline only	Underline with elaboration	Generate elaboration	Elaborate with study sheet
M	10.6	12.0	13.6	12.0
SD	4.8	3.8	3.9	5.1
n	28	30	27	29

(maximum score = 20)

Contrast	Beta	t	prob	Effect size
Generate elaboration vs Underline only	.25	2.22	.03	.67
Elaborate with study sheet vs Underline only	.14	1.19	.24	.32
Underline and elaborate vs Underline only	.13	1.14	.26	.32
$R^2 = .04$				

Table 4.9 presents the between group contrasts for the associative memory task when it is broken down into recognition of main ideas. The only statistically detectable finding is that the generate elaboration group recognized more facts that were main ideas than students in the other groups ($p<.01$). Although the elaborate with study sheet group did not outperform the underline only group at a statistically detectable level, the effect size was moderate (d = .40) suggesting that students in this group did better. This is reflected in the group means; the average score in the elaborate with study sheet group was almost 2 points higher than the average score in the underline only group.

Table 4.9. Between group contrasts on the associative memory task (target facts).

	Underline only	Underline with elaboration	Generate elaboration	Elaborate with study sheet
M	7.8	8.6	10.0	9.1
SD	3.5	2.9	3.0	3.8
n	28	30	27	29

(maximum score = 15)

Contrast	Beta	t	prob	Effect size
Generate elaboration vs Underline only	.29	2.54	.01	.66
Elaborate with study sheet vs Underline only	.18	1.57	.12	.40
Underline and elaborate vs Underline only	.11	.97	.34	.24

$R^2 = .06$

The between group contrasts for recognition of details on the associative memory task is presented in table 4.10. No contrast was statistically detectable at the $\alpha = .05$ level and the largest difference between means was less than 1 point. Thus, elaboration did not interfere with memory for details within the paragraphs and the groups performed equally well on recognition of detail-level facts.

A similar pattern of memory for details was found in the analysis of the memory for details subscale from the short answer test. Recall students were presented with three short answer questions about details of the animals and measured students' ability to recall detail level facts from the passage. For example, one question asked how fast the American Woodcock flies. Results of the regression analysis indicate no statistically detectable differences between the four groups (Table 4.11). In other words, the four groups recalled details from the passages equally well. Although the effect sizes suggest that elaboration with study sheet (d = .5) or reading the imbedded elaboration (d = .36) might have a small negative effect on memory for details, that effect arises out of the small variance in memory for details ($MS_W = .69$). The overall difference in means is slight.

Table 4.10. Between group contrasts on the associative memory task (details).

	Underline only	Underline with elaboration	Generate elaboration	Elaborate with study sheet
M	2.9	3.4	3.3	2.9
SD	1.5	1.2	1.2	1.5
n	28	30	27	29

(maximum score = 5)

Contrast	Beta	t	prob	Effect size
Generate elaboration vs Underline only	.11	.98	.33	.29
Elaborate with study sheet vs Underline only	.001	.01	.99	0.0
Underline and elaborate vs Underline only	.15	1.3	.20	.36

R^2 = 02

Table 4.11. Between group contrasts on memory for details subscale.

	Underline only	Underline with elaboration	Generate elaboration	Elaborate with study sheet
M	2.4	2.1	2.4	2.0
SD	.88	.82	.79	.82
n	28	30	27	29

(maximum score = 3.0)

Contrast	Beta	prob	Effect size
Generate elaboration vs Underline only	-.03	.08	0.0
Elaborate with study sheet vs Underline only	-.21	.80	-.50
Underline and elaborate vs Underline only	-.16	.18	-.36

R^2 = .04

A similar analysis was conducted on the assembly subscale. This subscale consisted of nine short answer questions assessing the degree to which students had assembled a link between the principle of adaptation and the characteristic of the animals illustrative of that principle. Results of the analyses (Table 4.12) showed that students who generated elaborations answered more short answer questions correctly than students who underlined. As well, students who had access to information during reading (elaborate with study sheet group) and students who were provided with the elaboration in text (underline with elaboration group) answered more short answer questions correctly ($p<.05$ for all contrasts). In other words, students who elaborated in some way or another were more likely to generate the intended and correct assembly of information.

An analysis of the responses to the assembly with prior knowledge subscale is presented in Table 4.12. Results in this table used a scoring scheme based on correct (1) or incorrect answers (0). But students need not have necessarily answered the question with the correct response. Responses were categorized as correct, plausible, indeterminant, or no response (see the scoring section of chapter 3). A second analysis was conducted to examine differences in response types across groups. The results are presented in Table 4.13 and Figure 4.1. In examining figure 4.1, keep in mind that the adjusted residual is analogous to a z-score. A larger residual indicates a larger deviation of the observed frequency from the expected. If the residuals are small, they should fall on a straight line in a normal probability plot. The critical points are points which deviate substantially from the straight line.

A chi-square test shows a statistically detectable pattern of responses[2]. Students who generated elaborations at the time of reading were less likely to not answer the question than students in the other groups ($z = -2.9$)[3]. Students who only underlined were least likely to respond with the correct answer ($z = -3.7$) and were most likely to not answer the question ($z = 4.1$).

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2 Responses across all questions have been pooled for comparison. In performing the chi-square test, there is an assumption of independence among answers to the questions; an answer is assumed to be independent of any other answer.

3 The standardized residual is a metric of the deviation of the observed from the expected cell frequency. It can be adjusted to make it normally distributed and can be interpreted as a standard normal deviate. The larger the residual, the larger the deviation from the expected frequency. Hinkle, Wiersma, and Jurs (1988) suggest a value of ± 2.0 is worth looking at. Haberman (1973) suggests normal probability plots using adjusted residuals for detecting deviant residuals. Large deviations from linearity are noteworthy.

Table 4.12. Between group contrasts on the assembly subscale.

	Underline only	Underline with elaboration	Generate elaboration	Elaborate with study sheet
M	3.1	4.4	4.4	4.3
SD	1.6	1.4	2.0	1.7
n	28	30	27	29

(maximum score = 9)

Contrast	Beta	prob	Effect size
Generate elaboration vs Underline only	.32	.005	.78
Elaborate with study sheet vs Underline only	.29	.01	.71
Underline and elaborate vs Underline only	.31	.007	.78

$R^2 = .09$

Table 4.13. Crosstabulation of response by group for the assembly to prior knowledge task.

	Underline only	Underline with elaboration	Generate elaboration	Elaborate with study sheet	Total
No response	57	38	22	34	151
	(4.1)	(-.3)	(-2.9)	(-.9)	
Indeterminant response	42	43	50	45	218
	(-.4)	(-.8)	(1.4)	(-.1)	
Plausible response	65	58	58	58	202
	(1.4)	(-.5)	(.7)	(-.2)	
Correct response	88	131	120	124	455
	(-3.7)	(1.3)	(1.5)	(.9)	
Total	252	270	243	261	

χ^2=27.8, p<.001, V=.09

Note: Numbers not in parentheses are frequencies. Numbers in parentheses are adjusted residuals.

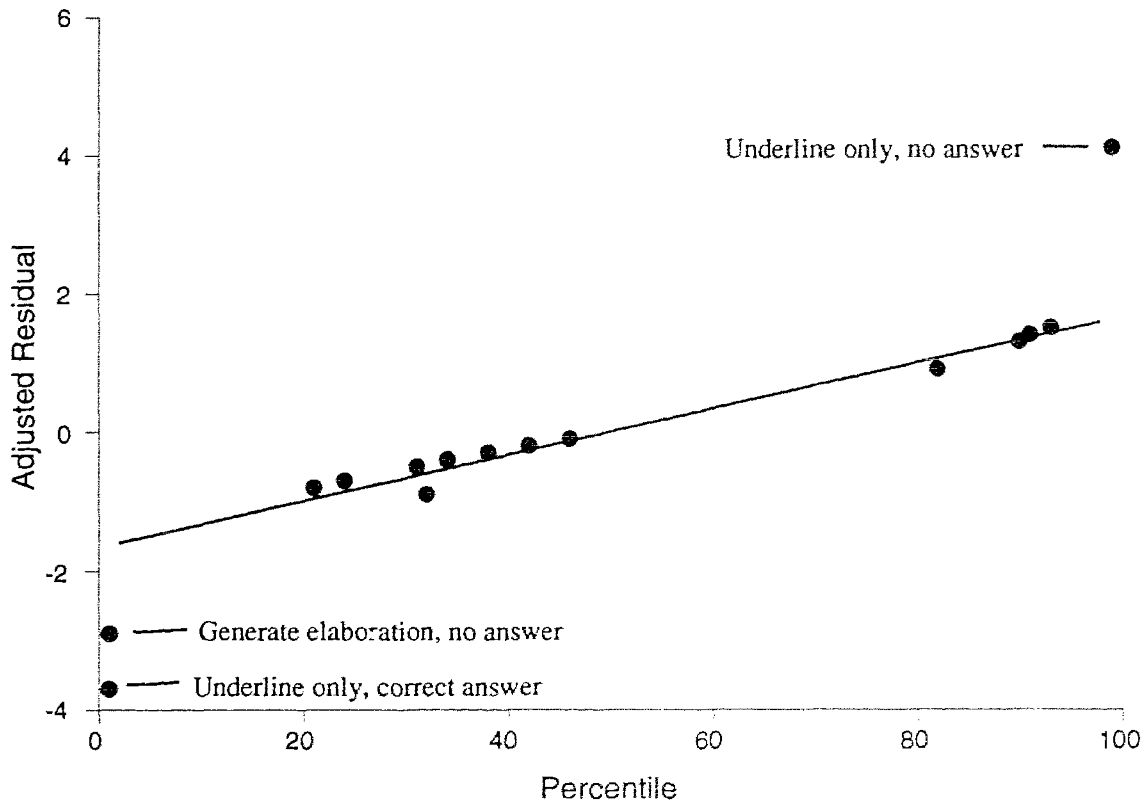

Figure 4.1. Normal probability plots of residuals in Table 4.10. Large deviations from normality are labelled.

The third subscale consisted of two novel problems which students were required to solve. However, for subsequent analysis the subscale is broken down into the two separate questions based on the low internal consistency coefficient reported earlier. It can be argued that two different questions are being asked. Question 13 (a novel problem solving task) asked how the American woodcock might get food to eat during the winter. Question 14 (the inference questions) asks how the snowshoe hare might protect itself in winter. This question can be successfully answered based on knowledge in the text. The student can make an inference that if the snowshoe hare turns white in winter, it must have been some other colour. A sensible response would be that it turns back to its summer colour (brown). In other words, the student can infer an answer based upon a mental model of the snowshoe hare which need not involve rules of adaptation. However, the correct answer to question 13 cannot be inferred from knowledge of the animal alone and requires a mental model based upon the principles of adaptation and not a mental model of the American woodcock.

Results of a priori contrasts on the inference question (Table 4.14) indicate students in the underline with elaboration group tended to make more correct inferences than students in the underline only group ($p<.05$) with a moderate effect size ($d = .55$). Generating elaborations, with or without the aid of the study sheet did not improve inferencing over underlining ($p>.05$).

Results of a priori contrasts (Table 4.15) suggest that none of the treatments were effective in problem-solving. There is a marginal effect in problem solving performance for students who generated elaboration ($p<.1$, $d = .2$) suggesting that elaborative interrogation has some small influence on problem solving. Overall, the three groups using elaboration techniques did tend to answer the problem solving question correctly more often than students who did not elaborate, but the effects are small and probably arise from the small within groups variance ($MS_W = .24$).

Table 4.14. Between group contrasts on the inferencing task.

	Underline only	Underline with elaboration	Generate elaboration	Elaborate with study sheet
M	.5	.77	.52	.56
SD	.51	.43	.51	.51
n	28	30	27	29
(maximum score = 1)				

Contrast	Beta	prob	Effect size
Generate elaboration vs Underline only	.02	.69	0.0
Elaborate with study sheet vs Underline only	.05	.89	.12
Underline and elaborate vs Underline only	.24	.04	.55
$R^2 = .05$			

Note: Data in this analysis have been scored correct (1) or incorrect (0).

Table 4.15. Between group contrasts on a problem-solving task.

	Underline only	Underline with elaboration	Generate elaboration	Elaborate with study sheet
M	.21	.27	.30	.28
SD	.42	.45	.46	.45
n	28	30	27	29
(maximum score = 1)				

Contrast	Beta	prob	Effect size
Generate elaboration vs Underline only	-.03	.08	.20
Elaborate with study sheet vs Underline only	-.21	.80	.16
Underline and elaborate vs Underline only	-.16	.18	.13
$R^2 = .005$			

Note: Data in this analysis have been scored correct (1) or incorrect (0).

The Effectiveness of Learning Strategies - Conditional Probabilities

In addition to contrasting the overall performance of the treatment groups on the outcome variables, conditional probabilities were computed to examine the effectiveness of the manipulations as students performed them. For example, if students underlined, did underlining contribute to recognition of a fact on the associative memory task? Did correctly answering a *why* question improve the likelihood of recognizing a fact on the associative memory task?

Conditional probabilities were computed using Bayes' theorem (Appendix D). Probabilities for use in the equation were obtained from crosstabulations which involved pooling student responses to their experimental tasks on all 15 paragraphs. The number of data points created by pooling was 1710, averaging 425 per group. Pooling was accomplished by matching students' performance on a given paragraph to their performance on the corresponding item on the associative memory task. The first conditional probabilities calculated examined the likelihood of correctly recognizing an item on the associative memory task given performance on the experimental manipulation during reading. Results are reported for each individual group.

The conditional probabilities for the underline only group are presented in Figure 4.2. The probability of correctly identifying the target sentence as the main idea or the paragraph is twice as great as that of identifying other information as the main idea (.66 versus .34), indicating the passages were relatively clearly written and students comprehended them. But when students underline the target idea as the main idea they are as likely to recognize the target fact on the associative memory task as they are to recognize the target fact if they underlined information other than the target idea. This probability of recognizing the target fact is quite a bit larger than randomly responding to the associative memory task (probability = .2). It seems that the act of underlining helped students remember ideas in the paragraph regardless of what they underlined.

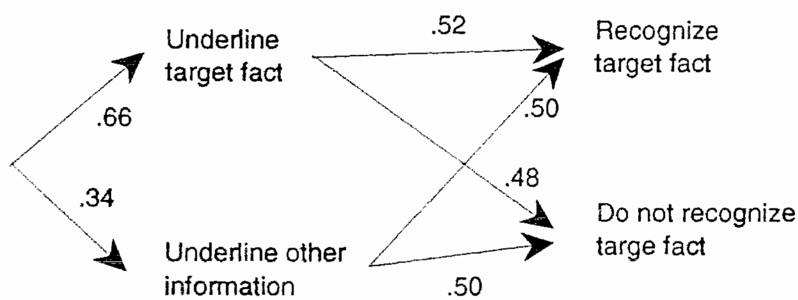

Figure 4.2 Conditional probabilities for students in the underlining only group.

The pattern of probability of recognition for students in the group which read an elaboration and underlined is similar to that the underline only group (Figure 4.3). Students underlining any information, whether it was the target fact, both the elaboration and the target fact, or other information were just as likely to not recognize the target fact as they were to recognize it. The exception to this statement is that students who identified the elaboration as the main idea were twice as likely to recognize the fact on the associative memory test as not recognize it. Identifying the elaboration as the important idea helped students learn the target fact.

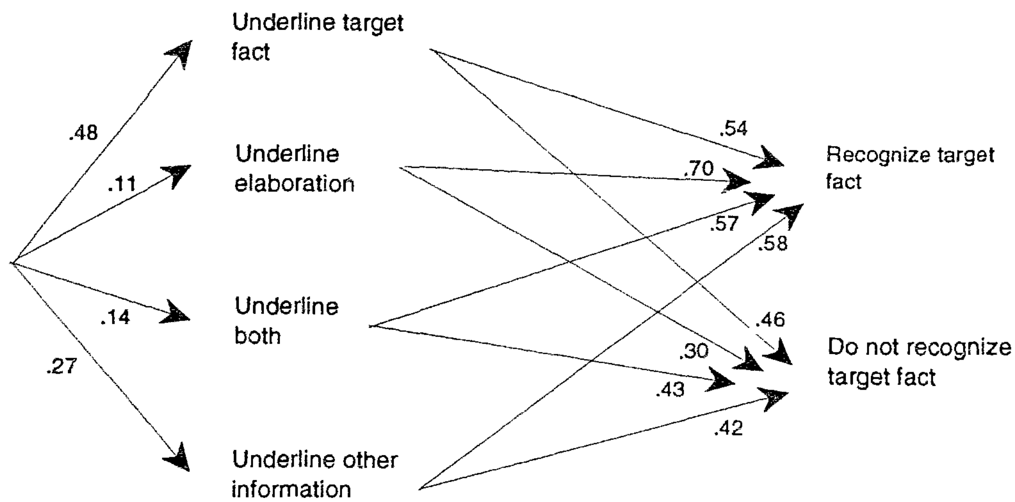

Figure 4.3. Conditional probabilities for students in the underline with elaboration group.

Students in the generate elaboration group were able to provide the correct and intended answers to the *why* questions (Figure 4.4) for 64% of the paragraphs. Those who provided the intended, correct responses to *why* questions while reading were more likely to recognize the target fact than not recognize it. Similarly, the students who provided indeterminant responses were far more likely to recognize the target fact as not recognize it, a finding consistent with prior research. Yet, the results also show that students who provide a plausible alternative are just as likely to not recognize the target fact as recognize it, a pattern similar to that of students who provide no answer.

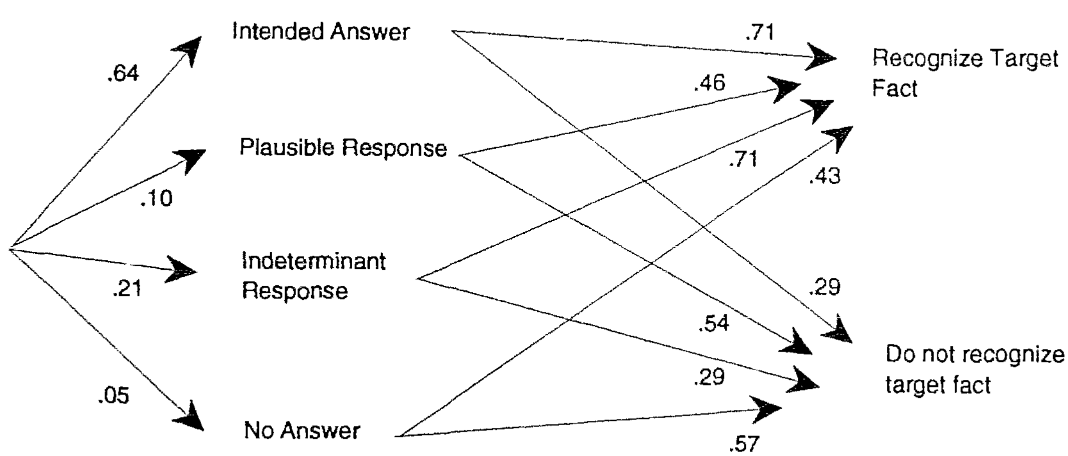

Figure 4.4. Conditional probabilities for students who generated elaborations.

The pattern of probabilities for the elaborate with study sheet (Figure 4.5) was highly similar to that of the generate elaboration group. The frequency distribution of responses in each group differs only by chance ($\chi^2 = 5.5$, $p>.90$). Because there were no statistical differences between these two groups on the achievement variables and the absolute differences were very small it would seem the performance of students in these groups is similar. Observation during the experiment suggested that students in the elaborate with study sheet condition may have reviewed their sheets but did not rely upon them for answering the questions.

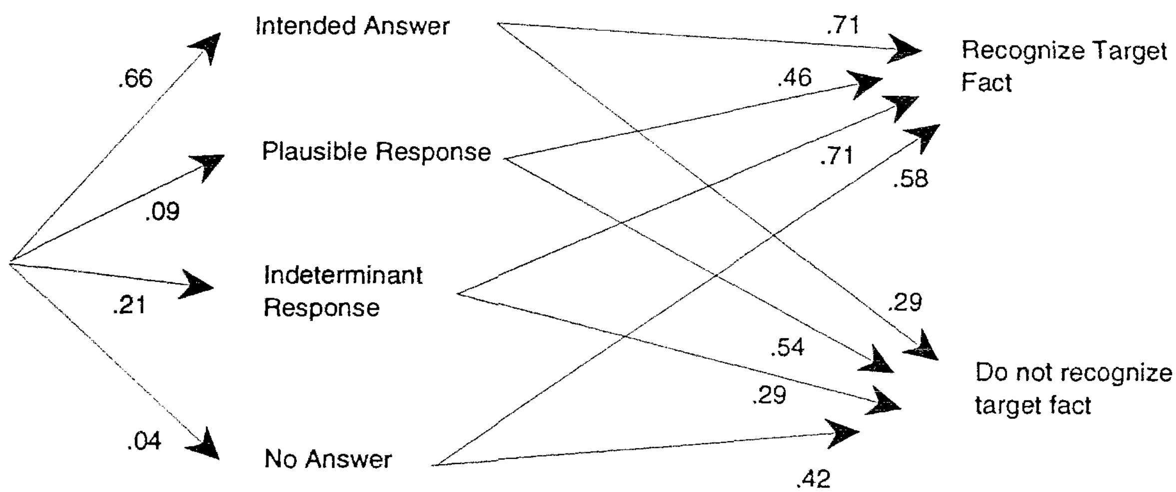

Figure 4.5. Conditional probabilities for students in the elaborate with study sheet group.

Because of the similarities between the generate elaboration group and the elaborate with study sheet group the data from these two groups were pooled to increase the sample size for computing conditional probabilities from about 420 for each group to 840 for the combined groups. This increase provides a more reliable estimate, particularly for outcomes where the number of data points would otherwise be small. For example, the number of instances in which no response was given to a *why* question increased from 21 in the generate group and 19 in the elaborate with study sheet group to 40 in the pooled group.

The pattern of conditional probabilities provides some stimulating results (Figure

4.6). First, not answering the *why* question does not aid learning. Students are as likely to not recognize the fact as recognize it if they do not answer the *why* question. Second, the quality of the answer does not seem to be an issue , a finding consistent with previous research (Pressley et al., 1988; Wood, 1989). Students who answer the *why* question with the correct answer are more likely to learn the fact as not learn it; students who generate an indeterminant response are more likely to learn the fact as not learn it. Yet, if students answer the *why* question with a plausible alternative, the probability of recognition is the same as that of no recognition, a finding consistent with Wood (1989) and Martin & Pressley (1991). The product of the assembly (elaboration) is an important factor in determining memory for the facts.

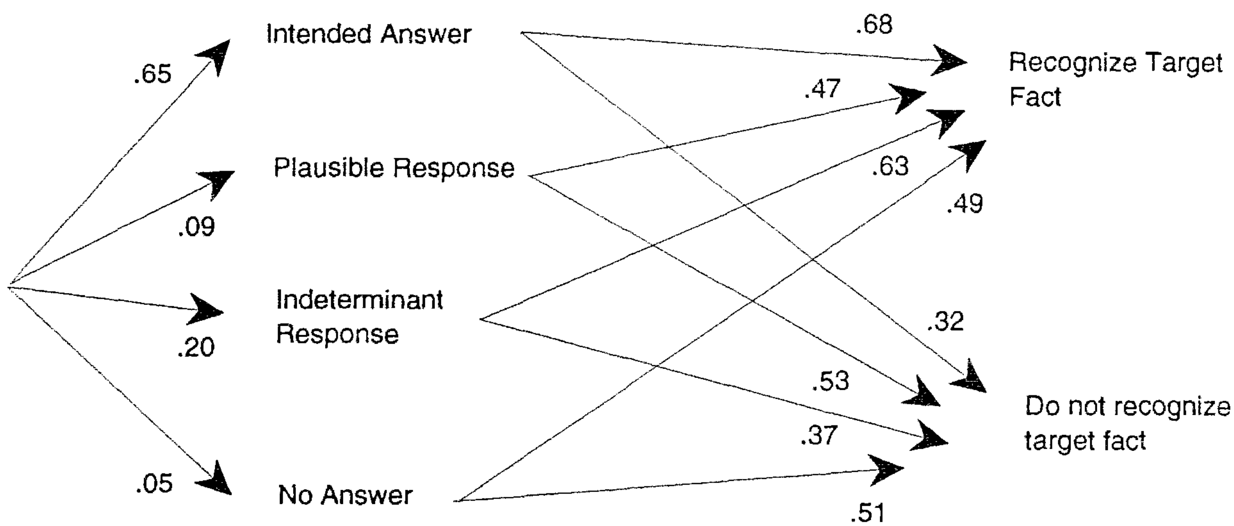

Figure 4.6. Conditional probabilities for generate elaboration and elaboration with study sheet pooled together.

Elaborative Interrogation and Prior Knowledge

Elaborative interrogation is thought to be an effective means of learning because it integrates new information with prior knowledge. Recall that students read information on laws of adaptation before reading the passage on animals. Hence, knowledge of these laws can be treated as prior knowledge. In this study, the links between the target facts and prior knowledge were assessed by means of short answer questions. If students answered the question correctly, then they presumably created the assembly at encoding, or created the assembly at retrieval through spontaneous inference. On the other hand, students in the underline only group should be less likely to create a link at encoding if they only engaged in the task of identifying the main idea and underlining it.

An earlier analysis suggests that students who elaborate are more likely to relate the target fact to the principle (Tables 4.12 and 4.13). An alternative method of examining this relationship is to compute conditional probabilities. In this context, the probability of recognizing the target fact is computed based upon types of responses to items on the assembly subscale. Recall that responses for the items on the assembly subscale were categorized as correct, plausible, indeterminant, or no answer. As in the previous computations, items were pooled for this analysis in a manner similar to that of pooling data for analyzing the type of elaboration made. While the question of independence of items may be raised, a justification for it can be argued from the low internal consistency coefficient. Because Cronbach's $\alpha = .44$, the consistency of responses across the items is moderate. In other words, if a student answered one question correctly, that student did not necessarily answer the other questions correctly. The number of data points obtained after pooling is 1026.

The conditional probabilities of recognizing the target facts on the associative memory task based upon type of answers given on the assembly subscale are presented in Figure 4.7. A residual analysis is presented in Figure 4.8 and Table 4.16. Together, these results suggest an interesting finding. The type of response on the assembly subscale is directly related to the likelihood of recognizing the target fact ($\chi^2 = 35.2$, $p<.001$, $V = .19$). The likelihood of recognizing the target fact is greatest when students are able to relate the fact to the principle ($z = 4.9$). Students were least likely to recognize the fact if they were not able to answer the question on the assembly subscale ($z = -4.7$). Equally interesting is the fact that students who make plausible links are less likely to recognize the target fact ($z = -2.2$) than students who make the correct link. Responding with an indeterminant answer does not enhance recognition of the target fact. It would seem that correctly relating the instance to the principle is either a prerequisite to learning, or a concomitant outcome by way of spontaneous elaboration. As Tables 4.12 and 4.13 reveal, students who only underline are least likely to respond with the correct answer and are more likely to not answer the question at all. Students who generated an elaboration are more likely to create an answer.

Table 4.16. Conditional probability of recognizing fact based on link made.

	Correct response	Plausible	Indeterminant	No response
Recognize fact	314	124	109	64
	(4.9)	(-2.2)	(.3)	(-4.7)
No recognize fact	149	108	71	87
	(-4.9)	(2.2)	(-.3)	(4.7)

$\chi^2 = 35.2$, $p < .001$, V=.19

Numbers not parenthesized are frequencies. Number in parentheses are adjusted residuals.

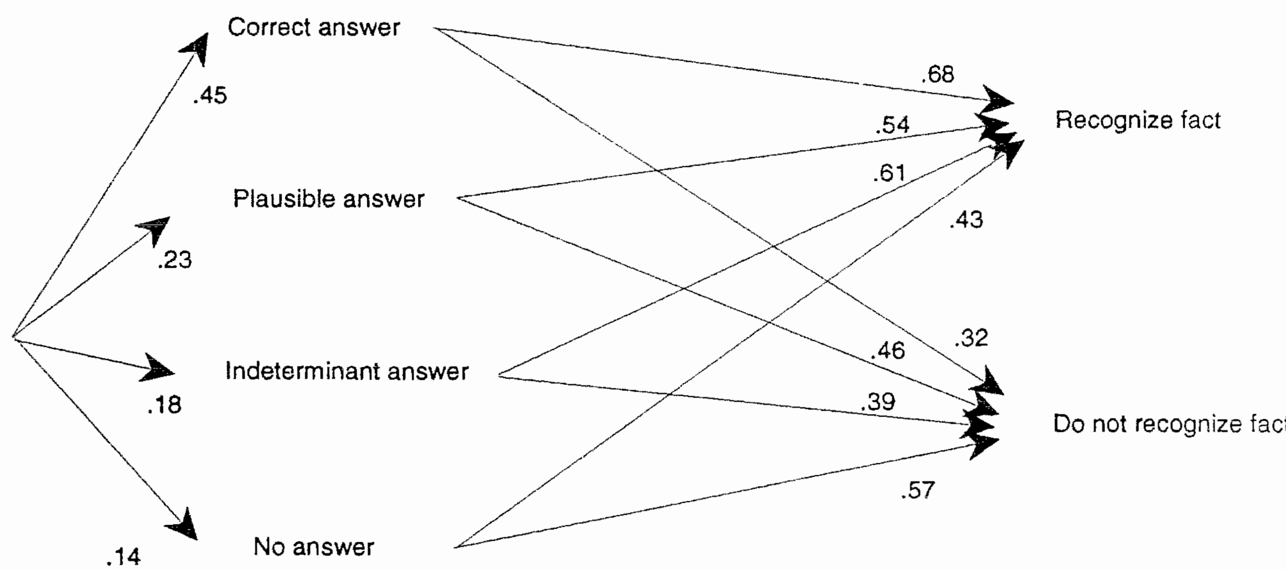

Figure 4.7. Conditional probability of recognition based on assembly to prior knowledge. All groups pooled.

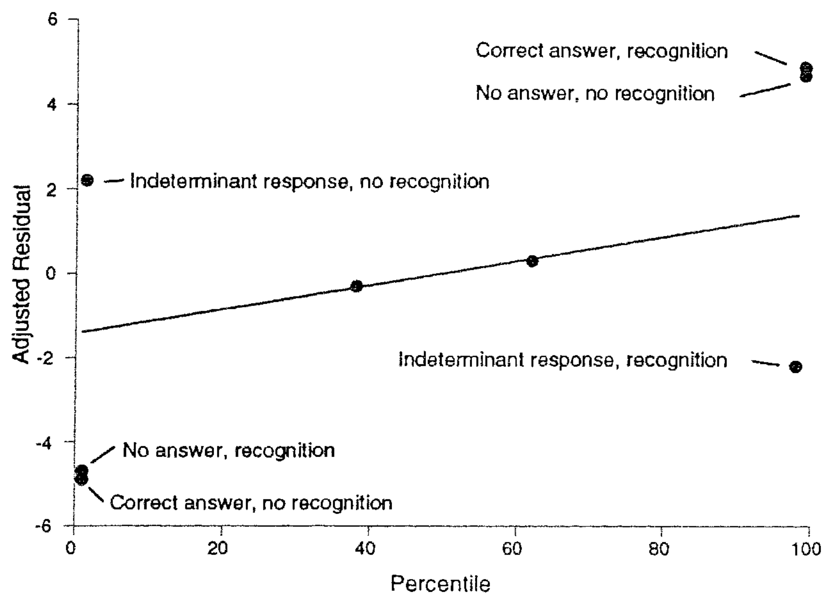

Figure 4.8. Normal probability plot of adjusted residuals, response type to assembly questions by recognition.

The conditional probability of recognition on the associative memory task given answers on the assembly with prior knowledge questions was examined within groups. It is predicted that the patterns of probabilities in the underlining group will be different than those in the underline with elaboration or generate elaborations group. The pattern of conditional probabilities for the underline only group is presented in Figure 4.9.

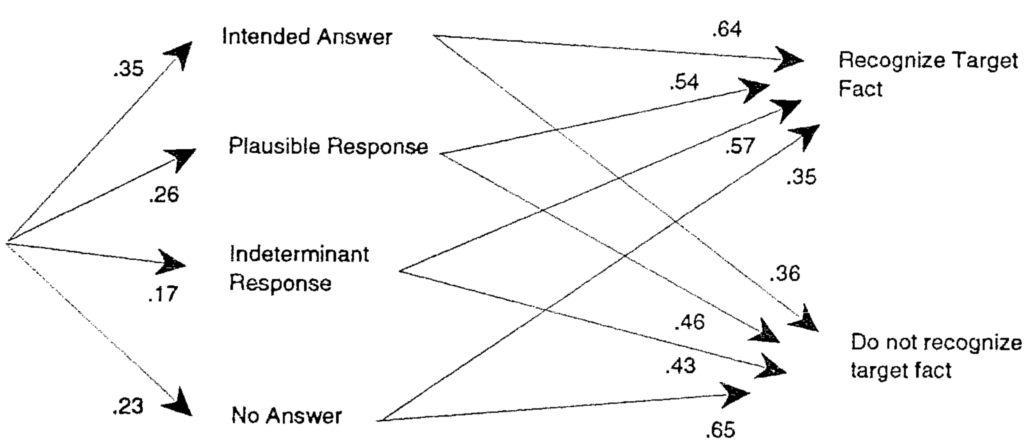

Figure 4.9. Probabilities of recognizing target fact conditional upon assembly with prior knowledge in underline only group.

Students in the underline only group who were able to generate the link between the principle and the target fact were twice as likely to recognize the target fact than not recognizing it. At the same time, the likelihood of recognizing the target fact when other answers are given is the same as not recognizing the fact. Students who could not provide an answer to the question were likely not to recognize the target fact.

Students in the underline with elaboration group also exhibited the greatest recognition if the correct assembly was made (Figure 4.10). That is, if students were able to relate the target fact to the correct principle, the probability of recognizing the target fact was greater than that of any other response type. Equally important to note is that creating an indeterminant link enhanced learning moderately, but creating a plausible link did not. In other words, the cognitive structure that results when students integrate knowledge is important for memory of the facts.

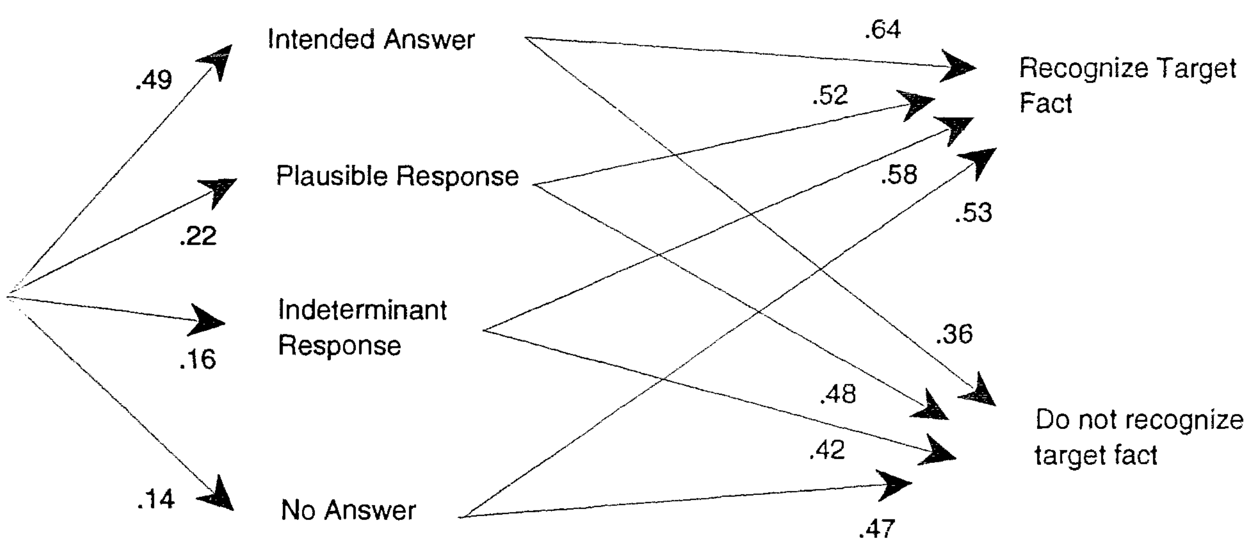

Figure 4.10. Probabilities of recognizing target fact conditional upon assembly with prior knowledge in the underline with elaboration group.

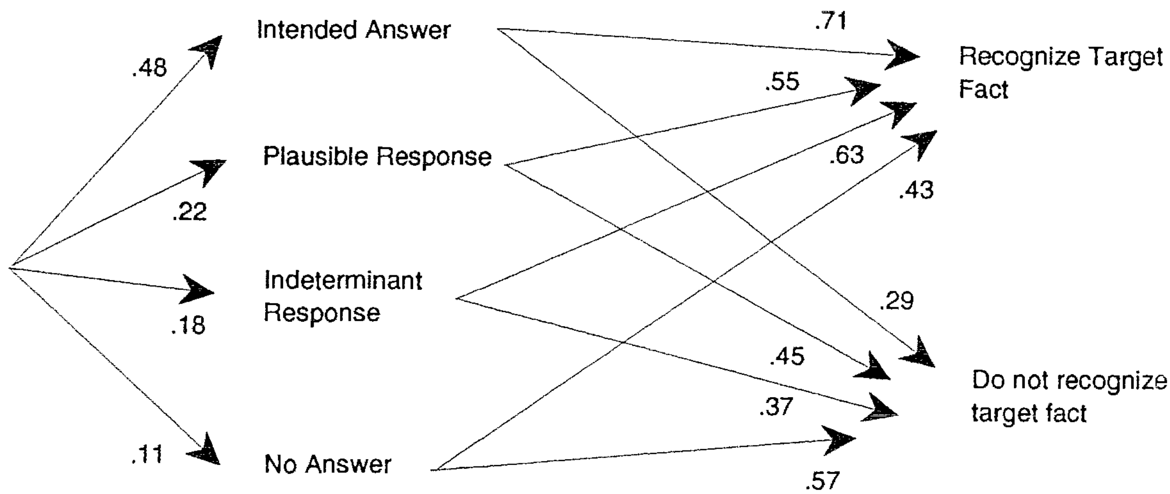

Figure 4.11. Probabilities of recognition conditional upon assembly to prior knowledge for students in the generate elaboration groups.

This pattern was weaker than that for students in the generate elaboration groups (Figure 4.11). Students who generated elaborations were more likely to recognize the target fact if they made the assembly between the target fact and the correct principle. If students used some other reasoning to create responses that were plausible, the probability of recognizing the target fact remains low, and they are approximately as likely not to recognize it as recognize it. Yet if the students respond with an indeterminant response, the probability of recognizing the target fact is greater than not recognizing the fact.

Figure 4.12 presents the conditional probabilities of making a link between the principle and the target fact. If students made an elaboration using the intended principle of adaptation, they were most likely to create the necessary link between the target idea and the principle. If students responded with some other elaboration they were not likely to make the intended link between the principle and the target fact In other words, using the principle for generating the elaboration is a strong predictor of creating the link between the target idea and the principle.

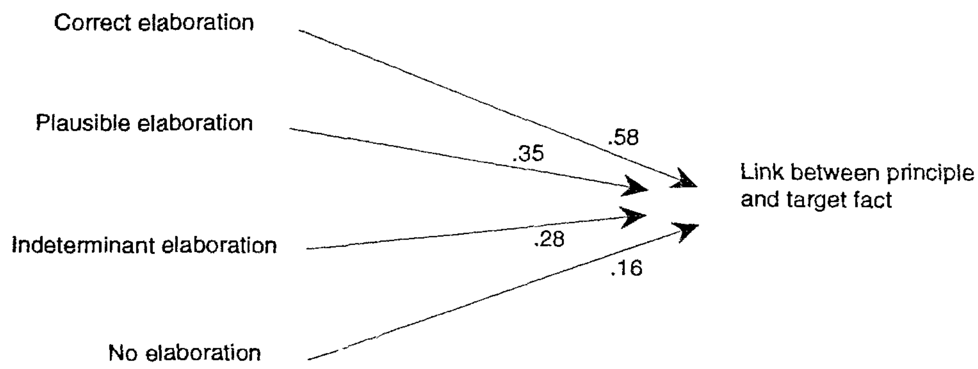

Figure 4.12. Conditional probability of type of link formed based upon type of elaboration made during reading. Generate elaboration and elaborate with study sheet groups combined.

A cautionary note: despite the fact that data from two groups were pooled and 504 data points were obtained, some cells in the crosstabulation table contained few people. Hence some probabilities are computed on cell frequencies less than 10. This may create some instability in the size of the probabilities. The amount of variation in the probability is hard to determine, but the observed pattern should remain the same. When students use the correct principle for elaboration they are likely to create a link between the fact and the principle. When students do not use the principle they are not likely to create that link.

Summary

It would seem that elaboration is a useful method for increasing learning. Students who engaged in elaborative interrogation tended to correctly recognize more items on the associative memory task. They were able to integrate the target fact with prior knowledge to a greater degree than students who only underlined either at encoding or by spontaneous elaboration at retrieval. Although creating an indeterminant link seems to aid learning, creating an incorrect yet plausible link does not enhance learning. The way in which students integrate new information with prior knowledge is important for learning. Elaboration does not interfere with memory for details; yet it did not improve students' ability to make inferences or solve novel problem.

Chapter 5: The Effects of Elaborative Interrogation

The between groups contrasts yielded a finding consistent with previous research. Students who generate elaborations are more likely to learn the elaborated fact than students who did not elaborate. However, there are surprising qualifications that need to be discussed since the results are not completely in agreement with prior research.

First, it is surprising that the size of the effect is not as large as indicated in previous research. Prior studies have reported effect sizes of .75 (Wood, 1989) or 1.1 (Woloshyn et al., 1990) standard deviations for the elaborative interrogation group over the reading control group on measures of learning. In this study the effect size was smaller (d=.67). This is surprising because the underline only group should not have engaged in elaboration. Rather, their task was to locate the main idea and underline it. The control groups in prior studies were allowed to read and study in any manner they desired, but they presumably did not elaborate. Given this situation, it is surprising that the effect sizes were not as large as earlier studies.

The smaller effect sizes may be attributable to two factors. First, placing a fact in a richer context increases its meaning. Students must engage in cognitions to comprehend the paragraph. Students in the underline only group read a fact that was expanded upon with 3-4 other sentences, selected the main idea, and underlined it. Engaging in such cognition leads to increased learning, which may lead to a reduction in the effectiveness of elaboration.

This argument can be quickly defeated by recognizing that all groups read the same material and the same extensions of the target fact existed in the materials (notable except is the underline with elaboration group). Hence, unless elaborative interrogation interacts with the presence of additional elaborating material, the effects of the extra elaborating material should have been the same across groups.

Another line of argument to consider is the cognitive processing that may have occurred. In prior research, students were presented with lists of facts to learn. It is possible that rehearsal was the predominant strategy of choice for students in the reading control groups of previous studies. In the present study, locating and underlining the main idea was the required task. Had students been required to merely rehearse the facts, less learning would have occurred and the results may have been closer to that found in previous studies. Requiring students to locate the main idea and underline may have boosted achievement over rehearsal in the control group thereby lessening the size of the effect of elaborative interrogation.

A second surprising finding is that students in the elaborate with study sheets group did not differ statistically from the underline only group. Although this group did perform better on the test of associative memory, it was not at a statistically detectable level. This is surprising because the performance of this group differed very little from the generate elaborations group on almost every measure. As mentioned earlier, the opportunity to utilize study sheets for aiding elaboration generation existed but most students did not utilize it. Hence, this group was highly similar to the generate elaborations group.

It was hypothesized that elaborative interrogation might cause the learner to attend to the target fact and divert cognitive resources to answering the *why* question at the expense of reading the remain sentences in the paragraph and remembering that information. Between groups contrasts indicated that elaborative interrogation did not interfere with memory for details. This suggests that students read the entire paragraph (at least the three that were tested) and remembered details from those paragraphs. Thus, elaborative interrogation did not interfere with or usurp processing of other information.

This finding is important because it says that the use of elaborative interrogation is not at the expense of general comprehension. That is, as students read the paragraphs and generate elaborations, the generation of elaborations does not prevent the learner from processing other information in the paragraph. Elaborative interrogation could be used in conjunction with other strategies as part of a study skills programme.

Another finding consistent with previous research is that the type of elaboration made affects memory for the target fact. Students who generated a correct and intended elaboration or an indeterminant elaboration were more likely to remember the target fact . On the other hand, in instances where students did not provide an answer to the elaborative prompt, the likelihood of recognition was substantially less than providing an answer. In other words, the act of generating the elaboration substantially increases the probability of learning the target fact, a finding consistent with the generation hypothesis.

Yet students who responded to the elaborative prompts with incorrect but plausible responses were as likely to not recognize the fact as recognize it. Learning was not improved if the elaboration was plausible (explanatory, but incorrect). This is a particularly puzzling finding since plausible answers were thought to reflect some sort of reasoning. Students who are responding with plausible answers should have some sort of mental model by which they can generate an answer. A plausible answer was recorded if the answer was incorrect but based upon reasoning that involved some other principle of adaptation. Yet the use of such models did not enhance learning, a finding consistent with other research (Wood, 1989).

While indeterminant elaborations increased recognition accuracy, there are good reasons for encouraging students to make the elaboration with the correct principle. Students who make the correct assembly between the target fact and the principle were more likely to recognize the target fact on the associative memory task than if they did not make that link. Students who make the correct elaboration while reading more likely to make the link between the principle and the target fact than any other type of elaboration or no elaboration. In other words, there is an epistemological consideration - the product of the assembly operation which relates the target fact to prior knowledge is important for learning the fact. This finding suggests that a qualified generation hypothesis explains the effect of the elaborative interrogation.

Given that elaborative interrogation does influence cognitive structure, it is surprising that students in the elaboration conditions did not outperform students in the underline only group on the inference and problem-solving tasks. It may be the case the tasks were too difficult for the students. The proportion of students correctly answering the problem-solving task was very small, and the proportion of students correctly answering the inference task was moderate. Given the items were difficult and students may have been fatigued, the opportunity for observing group differences may have been reduced. A separate study dedicated to examining the ability of elaborative interrogation to improve problem-solving is recommend.

Implications of the Study

This study provides several implications for practice. Elaborative interrogation has been shown to be effective in the context of reading material that is similar to that which students normally encounter in the course of their studies. This lays part of the foundation for promoting elaborative interrogation as a study skill to be used within a programme of study skills to aid memory for ideas.

As a study skill, the use of elaborative interrogation would involve four steps:

1) Read the paragraph and locate the main idea.
2) Use strategies, such as networking, to assemble links between ideas in the paragraph.
3) Generate a *why* question about the main idea.
4) Create an answer to the *why* question.

The success of elaborative interrogation hinges upon the ability of students to generate their own questions. In other words, students would need to become good self-questioners to effectively use elaborative interrogation. The efficacy of teaching students elaboration as a self-questioning strategy has been demonstrated by Wong and Sawatsky (1984) using sets of single sentences. Yet, the effectiveness of the self-questioning strategy in the context of a more complex reading passage remains to be demonstrated.

Since memory for a fact is influenced by the way in which it is related to prior knowledge, the questions students would generate would be important. Research by Martin and Pressley (1991) demonstrates the importance of asking the correct question. The success of elaborative interrogation as a study skill would rest upon students' ability to generate good questions. Research needs to be conducted to examine the students' ability to generate effective questions, and examine the efficacy for training students to generate good *why* questions.

One possible aid to training students to generate good questions is by teacher modelling. This study shows the effectiveness of elaborative interrogation as a means of enhancing learning. Thus, elaborative interrogation could become a tool in the teacher's repertoire for encouraging students to engage in cognitions. Teachers could use *why* questions as part of their teaching to get students to elaborate. At the same time, they are modelling the use of elaborative interrogation as a strategy.

Additional research should further examine the interaction between elaborative interrogation and other comprehension strategies if elaborative interrogation is to be used as a study skill. The results of this study provide preliminary evidence that elaborative interrogation does not interfere with other cognitive strategies. The manner in which students were instructed to perform their task should minimize any interference. Students were instructed to read the paragraph, and then answer the *why* question. The steps of the proposed study skill are arrange so that students read the paragraph and locate the main idea, and then elaborate. Sequentially, elaborative interrogation occurs after comprehension of the paragraph occurs, and should not interfere with comprehension.

A question still remains as to when elaboration should occur. Elaboration which occurs after comprehending a paragraph should not interfere with comprehension strategies. Yet, the elaboration is occurring between reading paragraphs. This raises the possibility that elaboration might not interfere with microstructure processes, but may interfere with macrostructure processes. In other words, elaboration may not interfere with understanding a single paragraph, but does elaborating after reading each paragraph interfere with the assembly of ideas across paragraphs? That is, does it prevent the student from relating ideas from one paragraph to another?

On the one hand, elaborating after each paragraph should not interfere with connecting ideas from paragraphs to each other. If the learner has stored the ideas contained in a paragraph to long term memory, they should be accessible at any future point for assembly operations.

On the other hand, when elaboration occurs, ideas contained in short term memory may be displaced by the retrieval of information used in the elaborative assembly. This means that when the learner want to connect ideas from paragraph B to ideas in paragraph A, he must retrieve the ideas about paragraph A from long term memory, and some cue must be provided at paragraph B to prompt the learner to do so. The act of elaborating may displace the ideas about paragraph A and lessen the likelihood of creating the assemblies between paragraph B and paragraph A. If the elaboration had not occurred between reading paragraph A and paragraph B, the learner may have had the ideas from paragraph A in short term memory and been able to make assemblies between the ideas. Therefore, elaborating between reading paragraphs may create interference with comprehension of the passage as a whole. It may be better to generate elaborations at the end of reading the entire passage rather than after each paragraph. Further research on this question is needed.

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Appendix A: Reading passage for session 1.

Characteristics and behaviours of animals.

Have you ever noticed that animals look different from each other? Some have long bills while others have sharp claws. Some have white feathers while others have thick fur. Have you also noticed that they behave in different ways? Some dig in the ground while others live in trees. Some migrate while others do not.

The way an animal looks, and the way it behaves lets the animal get food, protect itself , and reproduce. For example, lizards, especially chameleons, are capable of changing colours depending on their immediate surroundings. By changing colours, lizards are able to protect themselves by making themselves harder to see.

Scientists have discovered that the appearance of animals and the way in which they behave can be explained by some simple rules. Five of these rules are listed on the following pages.

Look carefully at each rule which has been highlighted in italics for you. **Read the example.** In your own words, **write the rule** in the space provided on the pink sheet called **Study notes**.

1. *Animals have special ways of protecting themselves from their enemies.*

One way for an animal to protect itself is by hiding, or *camouflage.* The shape and colour of an animal helps it blend in with its surroundings so it can hide from other animals. For example, a frog is green in colour. Being green helps the frog hide in weeds so other animals can't see it.

Another way for animals to escape is to flee. By running, swimming, or flying away, the animal can escape from its enemies. For example, the frog is a very good swimmer. When it sees an enemy, such as an owl, it can dive into the water and swim away.

Be sure to write this principle onto the pink study sheet.

2. *Animals live where they can easily find food.*

All animals need food to survive. One reason they live where they do is because food is available.

For example, muskrats like to eat water plants such as cattails and bulrushes. Therefore, a muskrat will live in ponds or marshes. On the other hand, a grouse will eat leaves, berries, twigs and bark. Thus the grouse can be found in forests and brushy areas.

Be sure to write this principle on the pink sheet.

3. *Animals have special ways of detecting enemies.*

Animals need to be able to detect their enemies and they have special ways of doing this. Some have a very good sense of smell. Others have very good hearing.

For example, the white-tailed deer has fairly large ears which give it good hearing. It can easily hear approaching enemies and this allows the deer to avoid its enemy.

Be sure to write this principle on the pink sheet.

4. *Animals have special ways of protecting their young.*

All animals protect their young and their are many ways of doing it. Some animals will distract the enemy by faking an injury. When the enemy sees the "injured" adult, it tries to catch the adult instead of the young. Another way for animals to protect their young is by charging the enemy. Sometimes this act of aggression and bravery will scare the enemy away.

One common way is to hide the nest. By hiding the nest, predators are not likely to find it and the young are safe. For example, the great blue heron builds its nest in the tops of trees. By doing this, the young are protected from predators because the predators cannot get find the nest.

Be sure to write this principle on the pink sheet.

5. *Animals have ways to ensure the population survives.*

Every animal tries to ensure that the young will grow to become adults so the population will survive. They do this in two ways.

First, some animals have alot of babies each year. By having alot of babies, the animal will make sure that some of the young will become adults. For example, a single female turtle will lay approximately 100 eggs each year. By doing this, the turtle makes sure that at least some baby turtles will grow into adults.

The second way to ensure that population survives is for the young animals to grow very quickly. By growing quickly the young become adults as soon as possible. They are able to defend themselves and obtain their own food. For example, baby loons will grow into adult loons within two months of hatching.

Be sure to write this principle on the pink sheet.

Without looking back, write down as many of the rules as you can remember in the space below. When you are done, go back and look for any you may have forgotten. Write them in the space below.

1.

2.

3.

4.

5.

Name ______________________________

Study Notes

Appendix B: Reading passages for the Second Session.

The snowshoe hare

One of the most common forest animals in Canada is the snowshoe hare. It can be found in most parts of Canada and some parts of the northwest US. Introduced into Newfoundland from Europe in the 1870's, it ranges from the east coast to the west coast, and North to the Arctic Ocean. They only place it can't be found is in the tundra regions of the far north.

Living on a diet of bark, plants, leaves, and twigs, the snowshoe hare prefers to live in areas of dense brush and vegetation. Thus, the snowshoe hare is found in most forest regions of Canada. In fact, large numbers of hares can be found in areas which have been recently burned by forest fires and are growing over again. The brushy growth of young deciduous trees and dense stands of young conifers enable the populations to flourish.

Underline the most important idea in this paragraph.

The snowshoe hare, which has sensitive hearing, has large upright ears. Typically, the ears are larger than the head and are covered in fur in the winter. Although the ears are larger than those of ordinary rabbits, they are smaller than those of the jackrabbit.

Underline the most important idea in this paragraph.

During the winter the coat of the snowshoe hare is white in colour. This change in colour is the result of changes in daylight and temperature. As the weather turns colder and the days become shorter, the outer hairs of the summer coat are shed and hairs for the winter coat grow in their place. The summer fur is gradually replaced by winter fur.

Underline the most important idea in this paragraph.

The female snowshoe hare, which is very fertile, gives birth about four times each year. Typically, the first births take place starting in late March and the last births take place in late August. Occasionally, some hares may be born in September, but this is rare. Each litter is born in groups at about five week intervals.

Underline the most important idea in this paragraph.

The nests of snowshoe hares are built under the thick branches of shrubs or bushes. The nests, which are called *forms,* can also be found in thickets or in the roots of tree stumps. The young are born in these nests but adult rabbits will also use them as resting spots during the daytime. Seldom do they dig burrows.

Underline the most important idea in this paragraph.

The American woodcock

One of the most unusual looking birds is the American woodcock. It has a long bill, extremely large eyes, and no neck. Despite its odd appearance, the bird is highly regarded by hunters as a gamebird. In fact, approximately 100,000 birds are killed by hunters each year in eastern Canada.

The American Woodcock, which eats mostly worms and insects, prefers to live in areas where the ground is soft and moist. They are well known for their tremendous appetites, and a single bird typically eats about 1/8 kg of food in a day. Most feeding occurs at dawn and dusk when the birds are most active.

Underline the most important idea in this paragraph.

When flying, the woodcock is fast and unpredictable. They tend to fly at low altitudes at speeds of about 40 kilometers per hour. They do not to fly very far at one time, although flights of several hundred kilometer have been recorded. When migrating, the woodcock tend to fly at dusk, and tend to follow river valleys and road ways bounded by forests.

Underline the most important idea in this paragraph.

Young American woodcock chicks grow very fast and are able to fly about 25 days after hatching. At this time, the young birds resemble adults. The young woodcocks can forage for themselves, and eat the same things as the adult woodcocks. Next spring, they will be ready to breed to produce more offspring.

Underline the most important idea in this paragraph.

Woodcock nests are very well hidden, typically along the edges of fields, or in bushy areas of young hardwood trees. The nests are built in small depressions in the ground, sparsely lined with twigs and leaves. The hen will lay four eggs in the nest and they will hatch in about 21 days.

Underline the most important idea in this paragraph.

Woodcocks, which feed at night and with their heads facing down, have unusually large eyes which are located towards the back of their head. They see in almost any direction, including behind them. To accommodate the unusual position and size of the eyes, the brain lies upside down in the bottom of the skull and the ear holes are in front of the eyes. In other words, the head is upside down compared to most other animals.

Underline the most important idea in this paragraph.

Richardson's Ground Squirrel

One of the most common sights on the prairies is the Richardson's Ground Squirrel. It can be commonly seen in pastures and fields, and is found in most parts of Alberta, Saskatchewan, and Manitoba. While many prairie animals such as the buffalo have become extinct the ground squirrel has continued to flourish.

The Richardson's Ground Squirrel has sharp eyesight. Often the ground squirrel can be seen sitting upright watching the horizon. It prefers to live in areas with short grass so it can look out over the surrounding area. Colonies of ground squirrels often have lookouts and they communicate with each other using a series of high pitch squeaks.

Underline the most important idea in this paragraph.

Wary of many enemies, the ground squirrel lives in tunnels it digs in the ground. There are many entrances and exits, but there is one main entrance which has a large mound of earth in front of it. Inside there are many chambers that are used for sleeping, storing seeds, and toilets. The entire system of tunnels may be as long as 14 metres and as deep as 1.8 metres.

Underline the most important idea in this paragraph.

Living mostly in grassland areas of the prairies, the ground squirrel eats a variety of leaves, flowers, and seeds. Common sources of food for the ground squirrel are the leaves of wild onion, sage, dandelion, and thistle. It also eats the seeds of wild sunflowers, pigweed, and bindweed. However, the ground squirrel will also eat the leaves of crops and vegetables, thus it has become a pest to farmers.

Underline the most important idea in this paragraph.

The young ground squirrels are born in a nest deep within one of the tunnels. The nesting chamber is about 23 centimeters in diameter and is located within the deepest part of the tunnel. It is lined with thick layer of dry grasses or any other soft materials it can find. Typically, there are 6 to 8 young born in the nest at a time.

Underline the most important idea in this paragraph.

The young grow quickly and are almost full grown in 3 months. They are born in March or April. By late May or early June they begin to emerge from the tunnels for the first time and by August they resemble adults. However, the ground squirrel is not fully mature until it is 1 year old and adult squirrels seldom live past 3 years of age.

Underline the most important idea in this paragraph.

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Living on a diet of bark, plants, leaves, and twigs, the snowshoe hare prefers to live in areas of dense brush and vegetation. Like most animals it lives where it can easily find food. Thus, the snowshoe hare is found in most forest regions of Canada. In fact, large numbers of hares can be found in areas which have been recently burned by forest fires and are growing over again. The brushy growth of young deciduous trees and dense stands of young conifers enable the populations to flourish.

Underline the most important idea in this paragraph.

The snowshoe hare, which has sensitive hearing, has large upright ears. This gives them an effective way of detecting enemies. Typically, the ears are larger than the head and are covered in fur in the winter. Although the ears are larger than those of ordinary rabbits, they are smaller than those of the jackrabbit.

Underline the most important idea in this paragraph.

During the winter the coat of the snowshoe hare is white in colour. The colour provides protection from enemies by making them hard to see. This change in colour is the result of changes in daylight and temperature. As the weather turns colder and the days become shorter, the outer hairs of the summer coat are shed and hairs for the winter coat grow in their place. The summer fur is gradually replaced by winter fur.

Underline the most important idea in this paragraph.

The female snowshoe hare, which is very fertile, gives birth about four times each year. This helps ensure that there will always be some adults and the population will survive. Typically, the first births take place starting in late March and the last births take place in late August. Occasionally, some hares may be born in September, but this is rare. Each litter is born in groups at about five week intervals.

Underline the most important idea in this paragraph.

The nests of snowshoe hares are built under the thick branches of shrubs or bushes. Hiding the nests helps protect the young hares from danger. The nests, which are called *forms,*can also be found in thickets or in the roots of tree stumps. The young are born in these nests but adult rabbits will also use them as resting spots during the daytime. Seldom do they dig burrows.

Underline the most important idea in this paragraph.

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The American Woodcock, which eats mostly worms and insects, prefers to live in areas where the ground is soft and moist. Like most animals, they live where they can easily find food. They are well known for their tremendous appetites, and a single bird typically eats about 1/8 kg of food in a day. Most feeding occurs at dawn and dusk when the birds are most active.

Underline the most important idea in this paragraph.

When flying, the woodcock is fast and unpredictable. This gives them protection from enemies by making them hard to catch. They tend to fly at low altitudes at speeds of about 40 kilometers per hour. They do not to fly very far at one time, although flights of several hundred kilometer have been recorded. When migrating, the woodcock tend to fly at dusk, and tend to follow river valleys and road ways bounded by forests.

Underline the most important idea in this paragraph.

Young American woodcock chicks grow very fast and are able to fly about 25 days after hatching. This ensures that there will always be some adults and the population will survive. At this time, the young birds resemble adults. The young woodcocks can forage for themselves, and eat the same things as the adult woodcocks. Next spring, they will be ready to breed to produce more offspring.

Underline the most important idea in this paragraph.

Woodcock nests are very well hidden, typically along the edges of fields, or in bushy areas of young hardwood trees. Hiding the nest helps protect the young from danger. The nests are built in small depressions in the ground, sparsely lined with twigs and leaves. The hen will lay four eggs in the nest and they will hatch in about 21 days.

Underline the most important idea in this paragraph.

Woodcocks, which feed at night and with their heads facing down, have unusually large eyes which are located towards the back of their head. This gives them a special way of detecting enemies. They see in almost any direction, including behind them. To accommodate the unusual position and size of the eyes, the brain lies upside down in the bottom of the skull and the ear holes are in front of the eyes. In other words, the head is upside down compared to most other animals.

Underline the most important idea in this paragraph.

Richardson's Ground Squirrel

One of the most common sights on the prairies is the Richardson's Ground Squirrel. It can be commonly seen in pastures and fields, and is found in most parts of Alberta, Saskatchewan, and Manitoba. While many prairie animals such as the buffalo have become extinct the ground squirrel has continued to flourish.

The Richardson's Ground Squirrel has sharp eyesight. This gives them a special way of detecting enemies. Often the ground squirrel can be seen sitting upright watching the horizon. It prefers to live in areas with short grass so it can look out over the surrounding area. Colonies of ground squirrels often have lookouts and they communicate with each other using a series of high pitch squeaks.

Underline the most important idea in this paragraph.

Wary of many enemies, the ground squirrel lives in tunnels it digs in the ground. This provides protection from enemies by making them hard to catch. There are many entrances and exits, but there is one main entrance which has a large mound of earth in front of it. Inside there are many chambers that are used for sleeping, storing seeds, and toilets. The entire system of tunnels may be as long as 14 metres and as deep as 1.8 metres.

Underline the most important idea in this paragraph.

Living mostly in grassland areas of the prairies, the ground squirrel eats a variety of leaves, flowers, and seeds. Like most animals, they live where they can easily find food. Common sources of food for the ground squirrel are the leaves of wild onion, sage, dandelion, and thistle. It also eats the seeds of wild sunflowers, pigweed, and bindweed. However, the ground squirrel will also eat the leaves of crops and vegetables, thus it has become a pest to farmers.

Underline the most important idea in this paragraph.

The young ground squirrels are born in a nest deep within one of the tunnels. Hiding the nest protects the young from danger. The nesting chamber is about 23 centimeters in diameter and is located within the deepest part of the tunnel. It is lined with thick layer of dry grasses or any other soft materials it can find. Typically, there are 6 to 8 young born in the nest at a time.

Underline the most important idea in this paragraph.

The young grow quickly and are almost full grown in 3 months. This ensures there will always be adults and the population will survive. They are born in March or April. By late May or early June they begin to emerge from the tunnels for the first time and by August they resemble adults. However, the ground squirrel is not fully mature until it is 1 year old and adult squirrels seldom live past 3 years of age.

Underline the most important idea in this paragraph.

The snowshoe hare

One of the most common forest animals in Canada is the snowshoe hare. It can be found in most parts of Canada and some parts of the northwest US. Introduced into Newfoundland from Europe in the 1870's, it ranges from the east coast to the west coast, and North to the Arctic Ocean. They only place it can't be found is in the tundra regions of the far north.

Living on a diet of bark, plants, leaves, and twigs, the snowshoe hare prefers to live in areas of dense brush and vegetation. Thus, the snowshoe hare is found in most forest regions of Canada. In fact, large numbers of hares can be found in areas which have been recently burned by forest fires and are growing over again. The brushy growth of young deciduous trees and dense stands of young conifers enable the populations to flourish.

Why does the snowshoe hare prefer to live in areas of dense brush and vegetation?

The snowshoe hare, which has sensitive hearing, has large upright ears. Typically, the ears are larger than the head and are covered in fur in the winter. Although the ears are larger than those of ordinary rabbits, they are smaller than those of the jackrabbit.

Why does the snowshoe hare need large upright ears and sensitive hearing?

During the winter the coat of the snowshoe hare is white in colour. This change in colour is the result of changes in daylight and temperature. As the weather turns colder and the days become shorter, the outer hairs of the summer coat are shed and hairs for the winter coat grow in their place. The summer fur is gradually replaced by winter fur.

Why would the snowshoe hare need to be white in colour during winter?

The female snowshoe hare, which is very fertile, gives birth about four times each year. Typically, the first births take place starting in late March and the last births take place in late August. Occasionally, some hares may be born in September, but this is rare. Each litter is born in groups at about five week intervals.

Why do female snowshoe hares give birth four times each year?

The nests of snowshoe hares are built under the thick branches of shrubs or bushes. The nests, which are called *forms,*can also be found in thickets or in the roots of tree stumps. The young are born in these nests but adult rabbits will also use them as resting spots during the daytime. Seldom do they dig burrows.

Why does the nest of the snowshoe hare need to be hidden under shrubs or bushes?

The American woodcock

One of the most unusual looking birds is the American woodcock. It has a long bill, extremely large eyes, and no neck. Despite its odd appearance, the bird is highly regarded by hunters as a gamebird. In fact, approximately 100,000 birds are killed by hunters each year in eastern Canada.

The American Woodcock, which eats mostly worms and insects, prefers to live in areas where the ground is soft and moist. They aie well known for their tremendous appetites, and a single bird typically eats about 1/8 kg of food in a day. Most feeding occurs at dawn and dusk when the birds are most active.

Why does the American woodcock live in areas where the soil is soft and moist?

When flying, the woodcock is fast and unpredictable. They tend to fly at low altitudes at speeds of about 40 kilometers per hour. They do not to fly very far at one time, although flights of several hundred kilometer have been recorded. When migrating, the woodcock tend to fly at dusk, and tend to follow river valleys and road ways bounded by forests.

Why would the American woodcock need to be fast and unpredictable when flying?

Young American woodcock chicks grow very fast and are able to fly about 25 days after hatching. At this time, the young birds resemble adults. The young woodcocks can forage for themselves, and eat the same things as the adult woodcocks. Next spring, they will be ready to breed to produce more offspring.

Why do woodcock chicks grow very fast?

Woodcock nests are very well hidden, typically along the edges of fields, or in bushy areas of young hardwood trees. The nests are built in small depressions in the ground, sparsely lined with twigs and leaves. The hen will lay four eggs in the nest and they will hatch in about 21 days.

Why would woodcock nests need to be well hidden?

Woodcocks, which feed at night and with their heads facing down, have unusually large eyes which are located towards the back of their head. They see in almost any direction, including behind them. To accommodate the unusual position and size of the eyes, the brain lies upside down in the bottom of the skull and the ear holes are in front of the eyes. In other words, the head is upside down compared to most other animals.

Why do American woodcocks need large eyes in the back of their head?

Richardson's Ground Squirrel

One of the most common sights on the prairies is the Richardson's Ground Squirrel. It can be commonly seen in pastures and fields, and is found in most parts of Alberta, Saskatchewan, and Manitoba. While many prairie animals such as the buffalo have become extinct the ground squirrel has continued to flourish.

The Richardson's Ground Squirrel has sharp eyesight. Often the ground squirrel can be seen sitting upright watching the horizon. It prefers to live in areas with short grass so it can look out over the surrounding area. Colonies of ground squirrels often have lookouts and they communicate with each other using a series of high pitch squeaks.

Why do Richardson's Ground Squirrels need keen eyesight?

Wary of many enemies, the ground squirrel lives in tunnels it digs in the ground. There are many entrances and exits, but there is one main entrance which has a large mound of earth in front of it. Inside there are many chambers that are used for sleeping, storing seeds, and toilets. The entire system of tunnels may be as long as 14 metres and as deep as 1.8 metres.

Why does the Richardson's Ground Squirrel live in underground tunnels?

Living mostly in grassland areas of the prairies, the ground squirrel eats a variety of leaves, flowers, and seeds. Common sources of food for the ground squirrel are the leaves of wild onion, sage, dandelion, and thistle. It also eats the seeds of wild sunflowers, pigweed, and bindweed. However, the ground squirrel will also eat the leaves of crops and vegetables, thus it has become a pest to farmers.

Why does the Richardson's Ground Squirrel eat the leaves of many plants?

The young ground squirrels are born in a nest deep within one of the tunnels. The nesting chamber is about 23 centimeters in diameter and is located within the deepest part of the tunnel. It is lined with thick layer of dry grasses or any other soft materials it can find. Typically, there are 6 to 8 young born in the nest at a time.

Why are the young born in nest deep underground?

The young grow quickly and are almost full grown in 3 months. They are born in March or April. By late May or early June they begin to emerge from the tunnels for the first time and by August they resemble adults. However, the ground squirrel is not fully mature until it is 1 year old and adult squirrels seldom live past 3 years of age.

Why do the young ground squirrels need to grow quickly?

Appendix C: Measures

Please answer the following questions about yourself.

I am in grade ____________

I am: ☐ Female ☐ Male

My mark in language arts or reading class is: _____________

	Not very interesting						Really interesting
	1	2	3	4	5	6	7
How interesting is science to you?	☐	☐	☐	☐	☐	☐	☐
How interesting are animals to you?	☐	☐	☐	☐	☐	☐	☐

How much do you know about each of the following animals? Indicate your answer with a check (☑).

	Nothing at all						Quite alot
	1	2	3	4	5	6	7
Snowshoe Hares	☐	☐	☐	☐	☐	☐	☐
Richardson's Ground Squirrel	☐	☐	☐	☐	☐	☐	☐
Ruffed Grouse	☐	☐	☐	☐	☐	☐	☐
Blue Herons	☐	☐	☐	☐	☐	☐	☐
American Woodcocks	☐	☐	☐	☐	☐	☐	☐
Whooping Cranes	☐	☐	☐	☐	☐	☐	☐

Please answer the following questions by indicating your answer with a check (☑).

	Not very interesting	2	3	4	5	6	Really interesting
	1	2	3	4	5	6	7
How interesting was learning about the reasons for the way animals look and behave?	☐	☐	☐	☐	☐	☐	☐

	Not very difficult						Really difficult
	1	2	3	4	5	6	7
How difficult was it to learn the reasons for the way animals look and behave?	☐	☐	☐	☐	☐	☐	☐

	Not very well						Really well
	1	2	3	4	5	6	7
How well do you think you know the reasons for the way animals look and behave?	☐	☐	☐	☐	☐	☐	☐

	Not very important						Really important
	1	2	3	4	5	6	7
How important is it to you that you learn the reasons for the way animals look and behave?	☐	☐	☐	☐	☐	☐	☐

	Not very hard						Really hard
	1	2	3	4	5	6	7
How hard did you try to learn the reasons for the way animals look and behave?	☐	☐	☐	☐	☐	☐	☐

Please answer the following questions by indicating your answer with a check (☑).

	Not very interesting	2	3	4	5	6	Really interesting
	1	2	3	4	5	6	7
How interesting was learning about these animals?	☐	☐	☐	☐	☐	☐	☐

	Not very difficult						Really difficult
	1	2	3	4	5	6	7
How difficult was it to learn about these animals?	☐	☐	☐	☐	☐	☐	☐

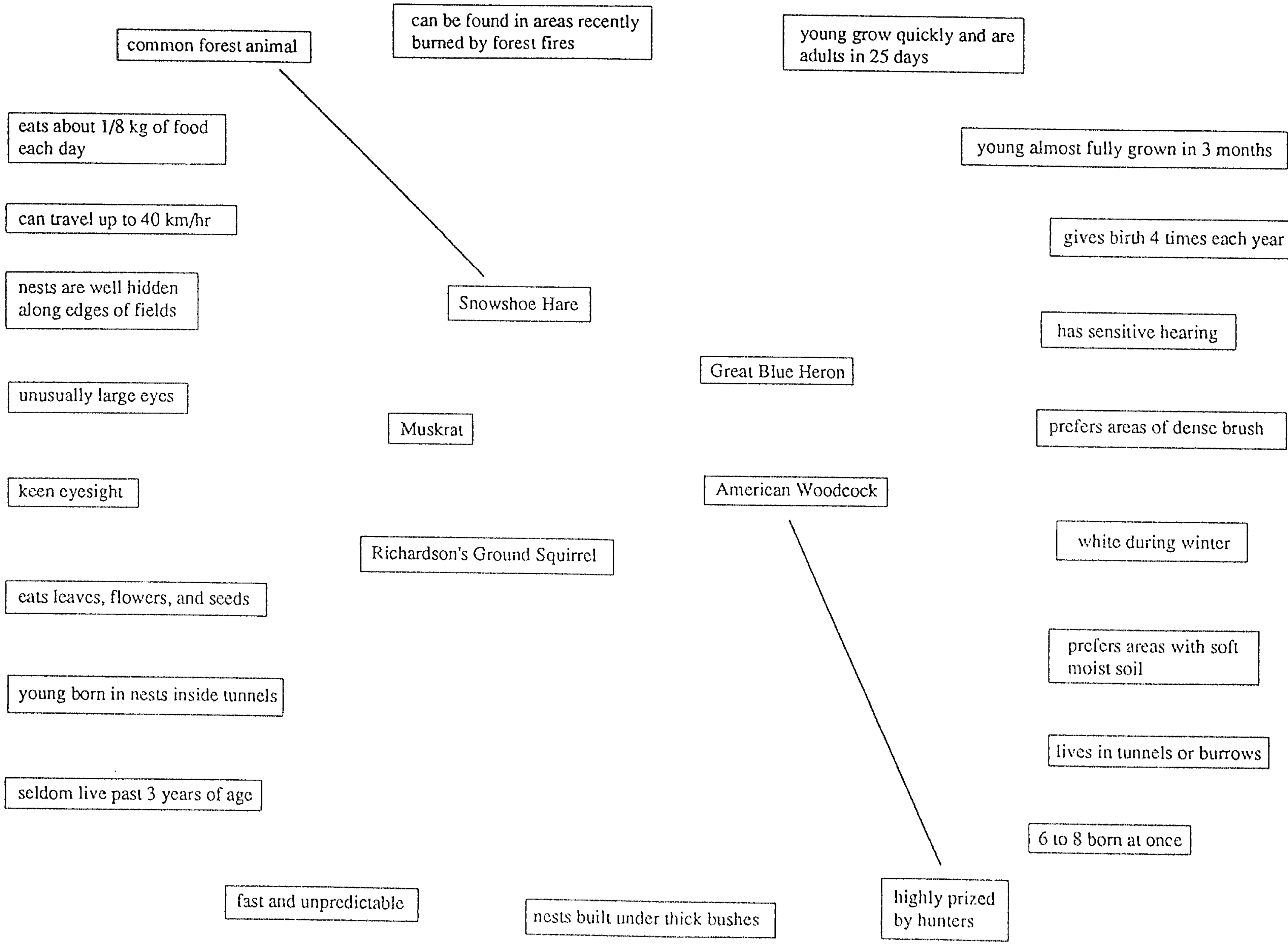
	Not very well						Really well
	1	2	3	4	5	6	7
How well do you think you learned the facts about these animals?	☐	☐	☐	☐	☐	☐	☐

	Not very important						Really important
	1	2	3	4	5	6	7
How important is it to you that you learn about these animals?	☐	☐	☐	☐	☐	☐	☐

	Not very hard						Really hard
	1	2	3	4	5	6	7
How hard did you try to learn the about these animals?	☐	☐	☐	☐	☐	☐	☐

The following page has a number of characteristics and behaviours of animals on it. In the center of the page are five animals. Read each characteristic and behaviour. Decide which animal it belongs to and draw a line from the characteristic to the animal. For example, the snowshoe hare is a common forest animal, so a line has been drawn from *common forest animal* to *snowshoe hare.* Similarly, the American Woodcock is highly prized by hunters, so a line has been drawn from *highly prized by hunters* to *American Woodcock.*

Match the characteristic to the animal. *Note: a characteristic might be true of more than one animal or it might not be true of any of the animals.*



common forest animal
can be found in areas recently burned by forest fires
young grow quickly and are adults in 25 days
eats about 1/8 kg of food each day
can travel up to 40 km/hr
nests are well hidden along edges of fields
unusually large eyes
keen eyesight
eats leaves, flowers, and seeds
young born in nests inside tunnels
seldom live past 3 years of age
Snowshoe Hare
Muskrat
Richardson's Ground Squirrel
Great Blue Heron
American Woodcock
young almost fully grown in 3 months
gives birth 4 times each year
has sensitive hearing
prefers areas of dense brush
white during winter
prefers areas with soft moist soil
lives in tunnels or burrows
6 to 8 born at once
fast and unpredictable
nests built under thick bushes
highly prized by hunters

Suppose you have just been asked to write an article for a wildlife magazine. The topic of this article happens to be the animals you have just read about, and the scientific reasons for their characteristics and behaviours. Based on the information you have read in your two sessions, write the story you would give to the magazine in the space below. Use the back of the page if you need extra space.

Please answer the following questions.

1. How does the snowshoe hare protect itself from its enemies?

2. How does the snowshoe hare detect enemies?

3. How does the snowshoe make sure that some babies will become adults?

4. How does the American woodcock protect itself from its enemies?

5. How is the American Woodcock able to get food to eat?

6. How does the American Woodcock protect its young?

7. How is the Richardson's Ground Squirrel able to get food to eat?

8. How does the Richardson's Ground Squirrel protect its young?

9. How does the Richardson's Ground squirrel make sure that some babies will become adults?

10. What causes the snowshoe hare to change colour?

11 How fast can the American Woodcock fly?

12. How many ground squirrels are born at one time?

13. The American Woodcocl eat worms and insects. How might the American woodcock obtain food to eat during the winter when the ground is covered with snow?

14. The Snowshoe protects itself by turning white in winter. How might the snowshoe hare protect itself during the summer time?

Appendix D. An example of categorization of student responses to assembly with prior knowledge questions.

Q1. How does the snowshoe hare protect itself from enemies?

Correct response	Plausible response	Indeterminant response
camouflage	hide in bushes	detect enemy
change colour	live in dense bush	it flies
blend in with surroundings	live in marsh	hides
turn white	long ears and good eyesight	hide
camouflage, fake injury, then attack	running fast	burrows
camouflage, hearing, speed	hide from enemy	so it won't get killed
turn white and hide nest	keen eyesight	
change colour, good hearing, and keen eye sight	big ears, dig ground	
camouflage and hearing	good hearing	
	hiding, running, hearing, trickery	
	hide in nests	
	run away	
	hide in snow	
	run unpredictably	
	run into bushes	
	charges enemies	
	hides nest and big ears	
	hearing and run fast	
	hear enemies and warn others	

Appendix E: An example of computing conditional probabilities.

Bayes' theorem is used to compute the probability of event A occuring given event B has occurred. In the context of this study, an application of Baye's theorem would be to compute the probability of recognizing the item on the associative memory given students in group 1 underlined the target idea.

In mathematical notation, Baye's theorem is expressed as:

$$P(A|B) = P(B|A)\,P(A) \div P(B)$$

where $P(A|B)$ is the probability of A occurring given B has happened; $P(B|A)$ is the probability of B given A, $P(A)$ is the probability of A and $P(B)$ is the probability of B.

In terms of the conditions in this study, A is the recognition on the associative memory task, B is underlining the target idea as the main idea. From the crosstabulation table below:

$P(A) = 216 \div 419 = .517$ $\quad$ $P(B) = 275 \div 419 = .655$

$P(B|A) = .664$

so $P(A|B) = .665 \times .517 \div .655 = .525$

Table E.1 Crosstabulation of recognition by ideas underlined for students in the underline only group.

	No recognition	Recognition	
Underline other information	72	72	144
Underline target information	131	144	275
	203	216	419