ABSTRACT

Title of dissertation: THE ASSOCIATION OF STUDENT QUESTIONING WITH READING COMPREHENSION

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In the field of reading comprehension, student-generated questions have been investigated within instructional contexts for elementary, middle school, high school, and college students. Although findings from instructional studies reveal that student-generated questions have an impact on reading comprehension, past research has not examined why student-generated questions improve text comprehension. This study investigated the relationship of student-generated questions and prior knowledge to reading comprehension by examining the characteristics of student-generated questions in relation to text.

A Questioning Hierarchy was developed to examine the extent that questions elicit different levels of conceptual understanding. The questions of third- and fourth-grade students (N= 208) about expository texts in the domain of ecological science were related to students' prior knowledge and reading comprehension. Reading comprehension was measured as conceptual knowledge built from text and by a standardized reading test. As hypothesized, questioning accounted for a significant amount of variance in students' reading comprehension after the contribution of prior knowledge was accounted for. Furthermore, low- and high-level questions were differentially associated with low and high levels of conceptual knowledge gained from text, showing a clear alignment between questioning levels and reading comprehension levels. Empirical evidence showed that conceptual levels of students' questions were commensurate with conceptual levels of their reading comprehension. This alignment provides the basis for a theoretical explanation of the relationship between reading comprehension and the quality of student questioning.

THE ASSOCIATION OF STUDENT QUESTIONING WITH READING COMPREHENSION

by

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Chapter I
Introduction

Theoretical Background

Students' questions are important to education and educational psychology for several reasons. First, student-generated questions constitute a centerpiece for student learning in a range of content domains. Asking questions within a knowledge domain or in reference to a specific topic is a useful cognitive strategy to facilitate learning (Baker, 1985; Nelson-LeGall & Glor-Scheib, 1985; Newman, 1992; Rosenshine, Meister, & Chapman, 1996). It has been further proposed that student questioning signals independence for the learner since questioning is an adaptive action of the student that helps regulate the student's own learning (Nelson-LeGall & Glor-Scheib, 1985; Newman, 1992).

Second, student-generated questions constitute a cognitive phenomenon that can reveal important aspects of a learner's knowledge structure. Student-generated questions can be described as requests for information within a topic or a knowledge domain. Such requests cannot be seen simply as a matter of looking for information that is explicitly stored in long-term memory. A lot of answers to our questions come from reasoning and knowledge that is not necessarily stored in long-term memory, but that suggest processes such as induction, deduction, analogy, etc. (Graesser, 1985). Therefore, the information seeking purpose that self-generated questions have in a learning situation imply tapping into processes and structures that are part of the learner's cognitive repertoire. "In its primary mode of use, a question is a device for seeking new information that is to be related to an existing knowledge structure. When to ask a question, and exactly what to ask, are both symptomatic of the status of the knowledge structure at issue, as well as, no doubt, the general intelligence of the asker" (Olson, Duffy, & Mack, 1985, p. 219).

Third, student questioning relates to complex inquiry-based tasks such as problem solving, science inquiry, and science processes. All of these tasks are initiated by questions. For instance, the relation of questions and problem solving has been studied with reference to the reading comprehension of narrative texts (e.g., Goldman & Varnhagen, 1983). In particular, questions that request inferential thinking such as questions about the themes of stories (e.g., friendship, loyalty, honor etc.) have been considered to relate to problem solving. Because the core of many stories consists of problem solving that requires social cognition and prior knowledge in order to draw conclusions from the theme of the story, questions can be regarded as good initiators of problem solving. Successful reading has many affinities with problem solving, so questions asked before or during reading a text may be informative data for monitoring the reader's understanding of a text (Olson et al., 1985).

In science, the inquiry process implies the identification and use of scientific facts in order to recognize the principles those facts reveal. This process is generally initiated by effective observation and the generation of relevant and informed questions about scientific phenomena. The ability to generate effective questions in this context reflects an understanding of the information gathered and the scientific phenomena under scrutiny. These questions will guide the approaches used during the process of science inquiry. The value of these questions resides in whether they request the necessary information to understand a scientific phenomenon.

Fourth, in addition to these cognitive characteristics, questions can also be described as intentional acts. A question posed by a student in a learning situation may be indicative of what that student wants to know, as well as of what that student already knows. It takes motivation, as well as skill, to ask a question. Part of the motivational aspect of a question lies in the intention or desire to find out about a topic. Asking a question has been viewed as an expression of will or commitment, as well as skill or knowledge (Dillon, 1990). However, despite their importance, the motivational attributes of questions will not be investigated here.

Lastly, student-generated questions are valued in education-at-large because of the influence they have on the learning process: An ideal learner has been described as an active, inquisitive, and curious student who processes knowledge deeply and asks a large and substantial number of questions (Graesser, McMahen, & Johnson, 1994). In reading in particular, the significance of student questioning was underscored in 1989 by Resnick and Klopfer (1989) in their book *Toward the Thinking Curriculum*. These authors called for the study of questioning by emphasizing its role in comprehension tests:

> Many reading comprehension tests, for example, display a degree of face validity. Students read passages and answer questions about those passages- surely one of the activities we expect people to do if they read with comprehension. We might wish for more extended passages, more complex interpretive questions, and certainly, opportunities for students to formulate questions about what they read instead of just selecting answers to a test-maker's questions. (pp. 208-209).

Rationale for this Study

The rationale for this study is based on three sets of findings from previous studies. First, studies have shown that instructional interventions in which students were taught to ask questions have an impact on reading comprehension (Ezell, Kohler, Jarzynka, & Strain, 1992; Nolte & Singer, 1985; Raphael & Pearson, 1985; Singer & Donlan, 1982; King & Rosenshine, 1993; Scardamalia & Bereiter, 1992; Taylor & Frye, 1992). This facilitation for instruction is supported by evidence showing that teaching elementary, middle- school, high -school and college students to generate questions in relation to text helps in fostering reading comprehension on both experimenter-designed and standardized tests (Singer, 1978; Cohen, 1983; National Reading Panel, 2000).

Second, previous studies have supported the notion that different *types* of questions can be taught to students (e.g., Ezell, Kohler, Jarzynka, & Strain, 1992; Raphael & Pearson, 1985; Scardamalia & Bereiter, 1992). Types of questions have been described mostly on the basis of the complexity of the information requested (Scardamalia & Bereiter, 1992; Cuccio-Schirripa & Steiner, 2000), the question stems used (King & Rosenshine, 1993), whether they were inferential or literal-text questions (Davey & McBride, 1986), and questions about the main idea in a text (Wong & Jones, 1982; Dreher & Gambrell, 1985).

Third, research in question-generation has underscored the influence of prior knowledge on types and number of questions asked (Miyake & Norman, 1979; Scardamalia & Bereiter, 1982; van der Meij, 1990; Costa, Caldeira, Gallastegui, & Otero, 2000). This influence has often been described by characterizing high-quality questions as questions that require the integration of prior knowledge with text information.

Previous literature, then, has supported that there is a facilitation of instruction for questioning. However, even though questioning instructional interventions have supported improved performance in reading comprehension, it is not known why students' questions in relation to text improve their comprehension of text. There are several plausible explanations for this relationship. Among those could be that the mere generation of questions improves reading comprehension by force of deeper text interaction. It is possible that having students wondering about a topic in a text and asking questions in relation to the topic contributes to active processing of the text. When asking questions, students are pondering relationships among different aspects of the text, hypothesizing, focusing on details and main ideas, using attention selectively (van den Broek, Tzeng, Risden, Trabasso, & Basche, 2001) and possibly anticipating conclusions about a text. Thus, questions might contribute to reading comprehension because questions facilitate active processing of the text. Moreover, it could be that the generation of specific types or levels of questions (i.e., "high level" or "thought provoking") is conducive to higher text comprehension. In that case, types of questions being taught could explain the instructional effects in previous studies. A third explanation is related to the possibility that the questions a student asks in relation to a text arise mainly from the student's background knowledge. As a result, questions would help organize and restructure background knowledge, either because questions would likely focus on aspects of background knowledge that were not entirely clear for the questioner, or because questions would use the extant background knowledge to probe for further information, deepening and completing this body of knowledge.

The absence of a theoretical rationale for the documented relationship between questioning and reading comprehension leaves any of the three alternative paths presented above, among others, as viable ones. All three explanations are feasible reasons for the association between questioning and reading comprehension, however none of these have been explicitly presented in past research. The present dissertation is based on the plausibility of these explanations, as well as on the assumption of the mutual independence of these three explanations.

Therefore, this dissertation is developed on the basis of the need to advance a theoretical rationale for the association between questioning and reading comprehension. In order to accomplish this task it is necessary first to have a better understanding of questioning itself. Only through a more thorough understanding of the types of questions students ask can one start to hypothesize the possible relationships between these two constructs. Even though previous literature has investigated types of questions students asked in relation to specific texts or within a subject matter (e.g., Scardamalia & Bereiter, 1992; Cuccio-Schirripa & Steiner, 2000), what has not been investigated in-depth is the relation of students' self-generated questions to reading comprehension, measured as conceptual knowledge built from text.

Indeed, it has been suggested that the process of question-generation is of equal importance to the process of question answering because, when students ask their own questions they are actively involved in processing information (King, 1995). However, despite the importance attributed to the questions themselves, these questions have not been examined or measured on the basis of the content they request, nor have question levels been associated with knowledge built from text. Therefore, it seems timely to focus upon the conceptual complexity of the questions students ask, as well as on the relationship between these questions and conceptual knowledge built from text. Such an account will help lay the ground for processing and for instructional studies on student questioning, especially research that focuses on developing reading comprehension strategies, as well as knowledge-based questioning in subject matter reading.

Measuring Questioning Levels

The focus in the current dissertation is not on teacher-posed questions or on the asking of questions that do not originate with the student. Rather, the focus is on the types of questions that are asked or self-generated by the student in a reading situation.

Types of student questions can be categorized according to several dimensions. Some of these dimensions consist of question-form or syntax, semantic features, pragmatic considerations of language, or content requests. In this dissertation students' questions are examined in terms of the complexity of the content they request. In the past, research has indicated the dearth of such an approach to questions. As Graesser (1985) aptly stated:

> Nearly all of the cognitive research on questioning has involved answers that are unidimensional, as opposed to answers with complex verbal responses. In the typical experiment, the subject comprehends stimulus material and then formulates a response on some dimension with a very restricted number of alternatives, e.g., YES versus NO, or a number on a rating scale…. Nevertheless, most questions invite answers with complex verbal descriptions (…) but cognitive psychologists have an underdeveloped understanding of complex questions (e.g., why, how, what are the consequences of) (pp. 9-10).

In this study, examining questions in terms of their content complexity implied categorizing questions according to the knowledge specification *within* the question as well as the type of information the question requests. In order to examine students' questions in relation to text I developed a question hierarchy that categorizes questions in terms of their requests for conceptual knowledge. Describing questions on the basis of requests for conceptual understanding permitted exploring the relationship that questions had with reading comprehension conceived as conceptual knowledge built from text. An abbreviated version of the Questioning Hierarchy is presented in Table 1.

Table 1

Questioning Hierarchy

Level	Question Characterization
Factual Information-Level 1	Request for a factual proposition. Question asks relatively trivial, non-defining characteristics of organisms or biomes, e.g., How much do bears weigh? Question is simple in form and requests a simple answer such as a fact or a yes/no type of answer, e.g., Are sharks mammals?
Simple Description-Level 2	Request for a global statement about an ecological concept or a set of distinctions to account for all forms of a species, e.g., How do sharks mate? Question may also inquire about defining attributes of biomes, e.g., How come it always rains in the rainforest? Question may be simple, but answer may contain multiple facts and generalizations.
Complex Explanation-Level 3	Request for elaborated explanations about a specific aspect of an ecological concept, e.g., Why do sharks sink when they stop swimming? Question may also use defining features of biomes to probe for the influence those attributes have on life in the biome, e.g., How do animals in the desert survive long periods without water? Question is complex and answer requires general principles with supporting evidence about ecological concepts.
Patterns of Relationships-Level 4	Request for elaborated explanations of interrelationships among ecological concepts, interactions across different biomes or interdependencies of organisms, e.g., Do snakes use their fangs to kill their enemies as well as poison their prey? Question displays science knowledge coherently expressed within the question. Answer may consist of a complex network of two or more concepts, e.g., Is the polar bear at the top of the food chain?

Pilot Investigation

To examine the relationship between student questioning and reading comprehension I first conducted a pilot study. This study is presented in Chapter III. This preliminary investigation had two main goals; first, examining the possible relationships between student questioning and reading comprehension, and second, testing some of the measures that were going to be used in the dissertation. Three hypotheses were tested in the pilot study with a sample of 196 third-graders.

Results of this preliminary investigation indicated that some of the hypothesized relationships between questioning, prior knowledge and reading comprehension were supported. Students' questions for each questioning task were found to be correlated with the respective measures of reading comprehension. In addition, student questioning accounted for a significant amount of variance in reading comprehension, over and above the variance accounted for prior knowledge, when students' prior knowledge was measured in the same topic (i.e., an animal's survival) that reading comprehension was measured. However, when students' prior knowledge was measured in the same knowledge domain (i.e., ecological science) but in a different specific topic (i.e., life in biomes versus animals' survival) than reading comprehension, students' questions accounted for variance in reading comprehension, but prior knowledge did not. The absence of variance explained by prior knowledge in reading comprehension within different topics may be attributable to the disparity in scope between a broader knowledge domain and the narrower focus of a specific topic within that domain. To overcome the limitation of measuring prior knowledge only in the broader topic of biomes, a second measure of prior knowledge in the specific topic in which passage-reading comprehension was measured, was used with the sample in this dissertation.

Results of the pilot investigation also sowed that student-generated questions that requested only factual information or simple types of answers (e.g., *yes/no* answers) were associated with levels of reading comprehension in the form of factual knowledge and simple associations. On the other hand, questions that requested conceptual explanations or probed for conceptual knowledge were associated with knowledge organized at a conceptual level with the necessary supporting factual information.

Dissertation Investigation: Research Questions

In view of these preliminary findings, the focus of this dissertation was on testing the pattern of relationships among questioning, reading comprehension, and prior knowledge for third and fourth graders with some modifications of the measures used. Specifically, the research questions for this dissertation examined the relationship between student-generated questions in reference to text and conceptual knowledge built from text, as well as testing the extent that the relationship between these two variables was independent of prior knowledge. The relationship between student-generated questions and reading comprehension was further examined by looking at the association between questioning levels and degrees of conceptual knowledge built from text. In order to examine these relationships, I tested the three hypotheses tested in the Pilot Study with a sample of 208 students in grades 3 and 4. Data for this sample were collected in December 2002. Students in this sample were administered seven tasks over five school days. These tasks were: (a) Prior Knowledge for Multiple Text Comprehension, (b) Questioning for Multiple Text Comprehension, (c) Multiple Text Comprehension, (d) Prior Knowledge for Passage Comprehension, (e) Questioning for Passage Comprehension, (f) Passage Comprehension, and (g) the Gates- MacGinitie reading comprehension test. The Gates- MacGinitie comprehension test provided a supplementary analysis of the relationships between questioning and comprehension measured by a standardized measure of reading comprehension. Three alternative forms were provided for the rest of the tasks. The dissertation investigation expanded the results of the Pilot Study by including third and fourth graders, thus facilitating the generalizability of the proposed relationships while allowing the examination of basic developmental differences in the questioning patterns of the two grades.

Chapter II
Literature Review

Purpose of Literature Review

This literature review concentrates on two main bodies of research: students' questioning in text comprehension and conceptual knowledge built from text. A review of extant research in these two topics was needed because this dissertation examined students' self-generated questions in relation to reading comprehension defined as conceptual knowledge built from text. These two topics are organized in two main sections.

By focusing on student questioning in this study, the first main section of this literature review covers research that examined how studies on questioning instruction contributed to the understanding of student questioning. Research on questioning has concentrated on teacher-posed questions on one side and student-generated questions on the other. The first two subsections focus on a brief overview of students' questions in oral conversations in order to discuss differences between student-generated questions versus teacher-posed questions. Describing these differences contributed to define questioning as students' self-generated questions in contrast to any other type of questioning activity that does not originate with the student (e.g., textbook questions, teacher-posed questions, etc.). Next, I narrowed the focus by describing research that specifically pertains to student-generated questions in relation to text comprehension. This subsection includes features of questioning as a reading strategy, its links to reading comprehension, and some of the empirical evidence that has discussed those features and links. In the next subsection, possible cognitive processes needed for successful questioning with text are discussed. This is followed by an introduction of the potential impact that levels or types of questions could have on student comprehension.

The bulk of this first section concentrates on studies in the two genres in which student questioning in relation to text has been most extensively researched: narrative and expository texts. Studies in questioning for narrative texts are presented first and questioning for expository texts second. Studies within each genre are presented following the instructional frameworks in which questions were investigated (e.g., instruction of literal types of questions; questions based on story structure, etc.). Taking into account that the specific focus of inquiry in this dissertation was student questioning in the domain of ecological science, the next subsection focuses on studies dealing with questioning instruction in relation to science texts and science processes for elementary school students. This subsection concludes with a brief review of the commonalities and differences within the literature in student questioning for narrative and expository texts.

One of the particular contributions that this dissertation brings to the field of student questioning is a question hierarchy that categorizes students' questions in terms of the conceptual complexity of their requests. Before introducing the question hierarchy for ecological science texts, I review two question hierarchies whose emphasis on content of questions and answers serve as research antecedents for the hierarchy hereby presented. One hierarchy was developed in the area of narrative texts (Graesser, Person, & Huber, 1992) and the other was developed for questions in a science domain (Cuccio-Schirripa & Steiner, 2000). A discussion on the advantages of a question hierarchy for instructional and research purposes precedes the presentation of the question hierarchy for ecological science texts that was used in this dissertation. This first section of the literature review concludes with a brief discussion of the impact of questions on reading comprehension.

The second main section of this review focuses on conceptual knowledge. This section starts with a characterization of reading comprehension understood as conceptual knowledge built from text. This introduction is followed by a broader perspective on types of knowledge (i.e., declarative, procedural and conditional knowledge) that serves to situate and set apart the particular type of knowledge of concern in this study. In order to characterize conceptual knowledge in detail I first define the construct and then describe its theoretical underpinnings (e.g., Norman, Gentner, & Stevens, 1976; Rumelhart, 1980). The subsections that follow describe conceptual knowledge extensively by means of representations of conceptual knowledge. Because my interest consists of conceptual knowledge built from text, studies that have described knowledge representations for both narrative and expository texts are presented. For expository texts, I specifically focus on a representation of conceptual knowledge that describes how different text elements can be organized in a science domain such as geology (Champagne, Klopfer, Desena, & Squires, 1981). In the next subsection, I review research on mental models for conceptual knowledge in the life sciences, the domain of interest in this dissertation. Additionally, because representations of conceptual knowledge have been considerably researched for narrative texts, I include a subsection on knowledge representations for stories. As it was done with the questioning literature, I conclude this subsection by underscoring the main differences between conceptual knowledge for narrative and expository texts. This is followed by a section that describes attributes of expository text, the text genre used in this dissertation.

In the next subsection, I focus on some of the tools that have been used to represent conceptual knowledge, such as concept maps, graphic organizers, and Pathfinder networks. The main features of these tools are underscored, especially in relation to the hierarchical organization of knowledge. I conclude this subsection with specific examples of two of these tools, a concept map on bat's survival and a Pathfinder network on the killer whale. These examples served two main purposes. First, they illustrated some of the features of knowledge representations for topics in the life sciences. Second, with the Pathfinder network example, the characteristics of one of the reading comprehension measures that were used to assess conceptual knowledge in this study were examined. The review of the literature concludes with the theoretical expectations and the hypothesized relationships between students' questions and reading comprehension that were tested in this dissertation.

Questioning in Text Comprehension

Questioning as an Area of Inquiry

Student questioning in cognitive psychology and in education has been studied from different research perspectives. The literature for both teacher-questions and student-generated questions is diverse and exhibits a variety of emphases (Dillon, 1982). As an area of research, teacher-questions has traditionally received the most emphasis, whereas student questioning had been initially thought of as a matter of pedagogic commentary rather than practice or research (Dillon, 1982). Students' questions became an area of inquiry when researchers' attention turned to instructional studies focused on students' questions and their role in learning (Hunkins, 1976; Dillon, 1982). In particular, there have been two significant approaches to examine students' self-generated questions, namely students' oral questions and students' questions in relation to text.

Students' oral questions. Student oral questions have been studied either in natural conversations or in instructional situations. The focus on questions in natural conversations has been on the psychological mechanisms thought to be responsible for the generation of questions. These mechanisms have included the correction of knowledge deficits, social coordination of action while engaging in a conversation, and the control of conversation and attention (Graesser, Person, & Huber, 1992). Oral questions in instructional situations have been examined as a process (i.e., the steps in the process of oral question-generation) (Dillon, 1988, 1990), as well as by the types of knowledge or conceptual content elicited by certain types of questions in tutoring sessions. Semantic and pragmatic features of oral questions have also been the focus of inquiry (Graesser, Person, & Huber, 1992).

When the focus has been on oral questioning as a *process*, researchers have concentrated on different stages of the process. These stages encompass the perplexity of the questioner that encourages the asking of the question, factors that affect the actual generation of the question such as social influences in classrooms, as well as the final stage of answering the question (Dillon, 1988, 1990). Some studies (e.g., van der Meij 1988, 1990; Dillon, 1990) have specifically focused on aspects of the middle stage in this process (i.e., the actual generation of the question) such as the questioner's assumptions or prior knowledge. These researchers have underscored the possible social costs of asking or posing a question in classroom settings. Posing a bad or poor question could result in revealing ignorance and losing status or being viewed as an independent problem solver (van der Meij, 1987, 1988). This type of research has contributed to understanding classroom social climate in relation to the presence of or lack of support from teachers and peers for student question asking as opposed to teacher-generated questions.

On other occasions, attention has been on the type of knowledge elicited through specific questions, rather than on the process implicated by the generation of the question. Questions have been examined during tutoring sessions in order to analyze the conceptual content of the question. Such questions were distinguished on the basis of whether they were shallow or elicited deep-reasoning patterns (Person, Graesser, Magliano, & Kreuz, 1994). A full taxonomy of questions has been derived from this and other studies with a similar focus (Graesser, Person, & Huber, 1992; Graesser et al., 1994). This taxonomy will be reviewed in some detail in a later section. Investigators also examined college students' oral questions as they related to lecture comprehension in order to learn how these questions developed during lecture presentation, as well as how they affected understanding of lectures (King, 1990).

When questions have been examined as an oral inquiry, written text or the process of reading had taken a back seat. However, questioning in classroom or instructional situations in which students generated questions in relation to text has also been examined. I turn to that evidence in the following sections.

Students' versus teacher's questions in relation to text. Student-generated questions in relation to text has been found to be a reading strategy that helps foster active comprehension (e.g., Singer, 1978; National Reading Panel, 2000). Questions that are student-generated have several advantages over teacher- posed questions. Researchers have underscored that teacher posed questions in relation to text tend to constrain students' reading in order to satisfy the teacher's purposes rather than the students' (Singer & Donlan, 1982). It has been argued that teacher- posed questions tend to emphasize evaluation of students' responses rather than the process of dealing with text ideas as students construct meaning by answering their own questions (Beck, McKeown, Sandora, Kucan, & Worthy, 1996). Other researchers have suggested that the active processing of students' questions may encompass a deeper processing of text in comparison to teacher-posed questions. Generating and answering one's own questions implies having to inspect text, identify ideas, and tie parts of text together (Craik & Lockhart, 1972). Furthermore, by engaging in these processes, students may become more involved in reading when they pose or answer their own questions and not merely respond to questions from a teacher or a text. Composing and answering their own questions may require students to play a more active, initiating role in the learning process (Collins, Brown, & Newman, 1990; King, 1994; Palincsar & Brown, 1984; Singer, 1978).

Evidence of student-generated questions in reference to text has been present in the two main genres in which reading comprehension has been studied: narrative and expository texts. Some evidence has emphasized the role of self-generated questions during story reading as it increases understanding and recall of narrative selections (e.g., Cohen, 1983; Singer & Donlan, 1982; Nolte & Singer, 1985). Empirical evidence for the narrative genre is more abundant than the evidence on student-generated questions for information or expository texts. The dearth of this type of evidence is one motive for the purpose of this study: questioning as it refers to self-generated questions by elementary-school students when reading expository text.

Questioning for Text Comprehension

Questions asked in different contexts and asked with different purposes are characterized by different features. For instance, questions in everyday situations or in natural conversations are mostly motivated by satisfaction of curiosity or requests for varied types of information that serve specific objectives in everyday events. The context and the purpose of these questions impact their type and format.

Van der Meij (1994) has suggested that a specific aspect that defines a question in a learning situation is that of an information-seeking purpose. When a reader poses a question in relation to a text, the question serves the information-seeking purpose of improving the understanding of that text. In other words, when student questioning is characterized as a reading strategy its value as such resides in guiding the reader to actively construct meaning by processing text in a deeper fashion and building knowledge from it. As a reading strategy, student questioning is supported by strong empirical evidence that purports that instruction of question-generation during reading benefits reading comprehension (National Reading Panel, 2000). Research reviewed by the National Reading Panel reveals that of the 16 categories of instruction, only seven strategies appeared to be effective and promising for classroom instruction. Within these seven strategies the strongest scientific evidence supported the effectiveness of having readers generate questions during reading (NRP, 2000). This evidence consisted of several studies that revealed the impact of students' questions on experimenter and standardized tests and a meta-analysis by Rosenshine, Meister, and Chapman (1996). In this meta-analysis the median effect size for 13 studies that used standardized reading comprehension tests as outcome measures was .36. However, only three of the 13 studies had statistically significant results. This has led to the conclusion that there is mixed evidence that general reading comprehension on standardized tests is improved as a result of instruction on questioning. On the other hand, the same meta-analysis revealed that 16 out of 19 experimenter-designed reading comprehension tests had statistically significant results in relation to questioning instruction (the effect size for the 16 studies that used experimenter- based tests was .87). These results have favored experimenter-based comprehension tests over standardized tests. Based on these results, the Panel recommended that question-generation may be best used as a component of a multiple strategy instruction program where strategies are used flexibly by teachers and students interacting over text.

In view of the results of their meta-analysis, Rosenshine et al. (1996) proposed that when students generate questions in relation to a text, the improvement in comprehension should not be seen as a direct result of the impact of having posed questions in relation to that text. Generating questions about material that is read does not lead directly, in a sequential manner, to reading comprehension. Rather, in the process of generating questions students need to search the text and combine information. It is these processes that help students comprehend what they read (Rosenshine, Meister, & Chapman, 1996). Therefore, it is highly probable that both the process of generating questions and the process of searching and locating the answers to their questions help students deepen their understanding of the text material.

Most theories of comprehension view successful understanding of a text as the identification of the elements in the text and the relationships among those elements to form a coherent structure, a mental representation of the text (e.g., Graesser & Clark, 1985; Kintsch, 1998; Trabasso, Secco, & van den Broek, 1984; van den Broek & Kremer, 2000). Thus, students' questions may enhance reading comprehension by tapping into the different elements and relationships of a text representation.

Different types of texts, however, vary in terms of the essential components and relationships their networks integrate. As it will be discussed in the conceptual knowledge section of this literature review, narrative comprehension may, for instance, focus on causal network representations (e.g., van den Broek, Tzeng, Risden, Trabasso, & Basche, 2001). Questions, then, may be a benefit to the comprehension of narrative texts to the extent that they support the text representation of a causal network (van den Broek et al., 2001).

On the other hand, if the text is expository or informational, reading comprehension will consist of a conceptual knowledge representation of that text

(Guthrie & Scaffidi, 2002 in preparation). Conceptual knowledge consists of content information that can be structurally organized within a knowledge domain or a particular topic in that domain. Central to this structural organization of knowledge are the interrelationships among the main concepts in the knowledge domain (e.g., Champagne et al., 1981; Chi, deLeeuw, Chiu, & Lavancher, 1994; Alao & Guthrie, 1999). Questions, then, may support expository text comprehension to the extent that they support building a conceptual knowledge structure that includes the main concepts and essential relationships among the concepts in the text.

The extent to how questioning as a reading strategy supports reading comprehension may vary as a function of the timing of the questions. Van den Broek et al. (2001) examined whether questions asked during reading had different effects on comprehension as compared to questions posed after reading. These researchers found that there was an interaction between questioning and reading proficiency in relation to the timing of the questions. Reading comprehension for elementary school students (4^{th}, 7^{th}, and 10^{th} grade) deteriorated when questions were posed during and after reading. However, college students benefited from questions during reading but not from questions after reading. Although informative, these results do not have a direct impact on the consideration of the timing of questions for this study. This is so because questioning in the study above consisted of experimenter-posed questions about text content rather than student-generated questions. For most of the studies reviewed here, students' questions are posed either before, during, or after reading. For the purposes of this study, questioning is defined as student-generated questions posed before reading, but after having browsed and inspected text for a few minutes.

The association between questioning and reading comprehension may also vary as a result of the prior knowledge of the reader. As others have purported, “In its primary mode of use, a question is a device for seeking new information that is to be related to an existing knowledge structure … Thus, there is a link between one’s own knowledge or understanding of a topic and the ability to ask a question about it” (Olson, Duffy, & Mack, 1985; p. 219).

Consequently, when questions are text-referenced or formulated to be answered by information contained in a given text or set of texts, they are indicators of what has been understood from the text or what is already known about a topic and what is yet to be understood from the text. In this sense, questions serve as a guide for further understanding of what is to be read mainly because they function as a bridge between prior knowledge, what has been understood from a text, and what is about to be read (Olson et al., 1985). By requesting information that is unknown to the reader, questions serve the function of filling knowledge gaps in the reader’s knowledge structure. The type of knowledge to be supplied by the appropriate answer to the question depends on the question type itself. In other words, the value of student questioning in relation to text resides in the processes of question-generation and question answering. Question-generation implies the skill of requesting information about what is not fully or what is partially known about a topic with the purpose of learning about it. Question answering implies a set of processes such as searching, integrating, and inferring information from text. Questioning, then, will benefit text comprehension to the extent that it provides information that contributes to the building of a network of the concepts and relationships within the text. Thus, it is possible that it is the types of questions asked in reference to a text that may reveal the type or attributes of the conceptual knowledge structure a reader builds from text.

Cognitive processes needed for successful questioning with text. Evidence provided in the next two sections will provide empirical support for the impact of students' questions on comprehension of both narrative and expository texts. However, it is difficult to find in the literature a unified theory of questions that explains *how* student questioning influences comprehension. No cohesive theory of questioning is available that discusses what the possible mediating processes between questioning and comprehension are. Even though the main purpose of this study is not to present such theory, I briefly mention some of the processes that may mediate questioning and comprehension. When questioning is conceived as a reading strategy that supports students' comprehension there are different possible cognitive processes that the generation of questions may be facilitating. Some of these processes may be:

1. Re-read and focus on content: By asking questions that are related to a specific topic, the questioner has to re-read the text and focus on text content in order to look for the appropriate answer.

2. Focus on text organization. By generating a question that is text-related the questioner needs not only to focus on text content but to focus on the organization of the text (e.g., information available in a specific section vs. information available across sections; attention to table of contents, glossary etc.). In other words, the questioner needs to attend to the *macrostructure* within the text.

3. Focus on genre structure. Questions may direct attention to structural aspects of a genre as in the case of story structure. If the question inquires about the main idea, this

component of the story will be the focus of the reader's attention rather than supporting details of the obstacles that the main character encounters, which generally tend to be of secondary importance. In the case of expository texts, different types of questions will direct attention to different components of the structure of the text. For example, if the questions request conceptual information, attention will be directed to whole sections or information across sections that can provide a conceptual answer, rather than to specific factual information contained in a single sentence.

4. Selective attention. To locate the information requested by the question, the processes mentioned above must be accompanied by selective attention. The questioner must be attentive to certain portions of text information in order to select the appropriate sections of text to supply the correct answer to the question. This may imply choosing specific text sections of the text to inspect, as well as integrating information across text sections. Van den Broek et al. (2001) have called this process the "specific attention perspective" because questioning makes the reader concentrate predominantly on the information contained in the questions and answers and in the connections between them. Therefore, readers' comprehension and memory will only be improved for the sections of texts that are targeted by the questions asked. On the other hand, these researchers also propose a "general attention perspective" for which questioning results in improved comprehension of the whole text. "Readers are motivated to give good answers and thus put more effort into understanding the text as a whole. As a result the effects of questions are not limited to the information targeted by the questions…but extend to the entire text" (van den Broek et al., 2001, p. 522).

5. Integration of information. Integrating information across text(s) assumes selective attention as well as the ability to look for information that may not be present in the text at hand. Some questions may inquire about information not available in a particular text and thus, the reader may need to look for information in other sources and integrate it in such a way that an appropriate answer can be provided. This process may also entail integration of text information with the questioner's prior knowledge or integration of information across sentences, paragraphs, or sections within the same text.

Carrying out and completing these cognitive processes entail a deep and thorough understanding of text. However, not all types of questions lead to the completion of all of these steps. It is highly probable that simple questions will lead to simple answers that can be easily located, and that complex questions will lead to answers requiring more elaborate processing which, in turn, will construct more elaborate answers. The characterization of question complexity varies in the literature as a function of how questioning has been defined. Question types have been defined differently for expository and narrative genres, and even within each genre, there is a range of definitions for diverse question types.

Impact of levels of questions on cognitive processes of text comprehension. Even though types or levels of questions may vary according to genre and even within genres, it is probable that most questions influence comprehension through all or some of the mediating processes previously described. Depending on the text genre, questions will enhance the perception of the particular text structure, (e.g., story structure for narrative texts, and conceptual knowledge structure for information texts). By asking a particular question, specific aspects of the text structure will stand out in relation to others.

Question complexity, in turn, will vary as a result of the aspects of the structure it taps into. For instance, if a question asks about the main character's goal(s) in a story, that question contains more elaborate knowledge than a question inquiring about the main character's name. This is due to the kinds of mediating processes involved in providing an answer for each kind of question. In the case of the former question, the main character and his goals are highlighted as a result of searching for the answer to the question. This aspect of story structure is brought to the foreground due to that specific question. Thus, a question may influence comprehension because of the aspects of text structure it brings to the foreground. These aspects may be concepts or facts in the conceptual knowledge structure built from an expository text or a character's motives and goals within a story.

Questioning in this study is defined as students asking self-initiated questions before or during reading a specific text. This study uses a question rubric, built within a hierarchical structure that varies as a function of the complexity of the knowledge the question elicits in reference to an expository text in science. At the basic level of this hierarchy, Level 1, a question asks for a fact or a trivial feature, whereas at the highest level, Level 4, a question asks for a relationship between ecological concepts, or a science principle. As it will be discussed later, the progression in knowledge from Level 1 to Level 4 in the hierarchy is based on the complexity of the answer required in each case and not merely on a greater amount of information. Because the answer to a Level 4 question is much more complex in terms of the information to be attended to (i.e., concepts versus facts) and the integration of information it requires (across different sections in a text or even across different texts), it is reasonable to speculate that knowledge construction for an answer to a Level 4 question will imply many, if not all, of the cognitive processes previously described.

In other words, the question hierarchy to be presented in this study attempts to capture different question levels. Question levels are defined in terms of the complexity of the knowledge they request. Complexity of knowledge in each level is described in the hierarchy itself. However, as it will be discussed in detail later, knowledge of higher complexity is characterized by conceptual knowledge that is well structured and properly linked. Type or degree of knowledge is evidenced not only in the answer provided to a given question, but in the mediating processes required to provide that answer. Simply put, conceptual knowledge that is well structured and properly linked will be the outcome of a well-formed and high-level question. Therefore, the posing of a high-level question anticipates that conceptual knowledge can be organized in a hierarchical and principled way.

Impact of Questioning on Narrative and Expository Text Comprehension

Self-generated questions have been studied in both narrative and expository genres. As mentioned, student questioning has not always been discussed in terms of its effects or its association with reading comprehension, nor in terms of the possible mediating processes with text. However, important conclusions can be derived from the literature in terms of the role of self-generated questions on comprehension for both narrative and expository texts.

Narrative texts

Many investigators have assumed that self-generated questions can improve reading comprehension (e.g., Ezell, Kohler, Jarzynka, & Strain, 1992; Raphael &

Pearson, 1985; Nolte & Singer 1985; Rosenshine et al., 1996). This assumption has led to text-referenced questions being examined in both genres: narrative and expository. However, researchers have not always explicitly defined the improvement of reading comprehension through questioning as one of their goals, which has led to varying emphases on the types of questions or question-frameworks taught to students.

In the case of narrative texts, the role of questioning in comprehension has been revealed mostly through instructional research in which different types of questioning instruction has been shown to improve comprehension for elementary and middle-school children. The fact that researchers in this area have attempted to improve reading comprehension by focusing on the instruction of questions assumes a relationship between questions and comprehension: students who ask questions in reference to a story can improve their comprehension of the story. Instruction on questioning, however, has varied in the conceptualization of what constitutes good questions. Variations in the type of question instruction has ranged from questions based on story structure categories to questions categorized according to the location of their answers in the text. Even though most research in question-generation for narrative text supports the positive impact students' questions have on reading comprehension, some types of instruction seem to be more effective than others.

Instruction of literal types of questions. One type of questioning instruction has focused on the generation of questions at the literal level; that is, questions that could be answered by specific explicit information in a given story (Cohen, 1983). Third-grade students were taught to discriminate between questions and non-questions (i.e., form of a question: question mark, a question asks for an answer, etc.) and to discriminate good from poor questions: a good question starts with a question word (*who, where, what, how, why*) and can be answered by the story. Instructional materials included a pre- and a post-criterion test and a standardized test. The criterion test included five short stories. Students answered the question, “What is the story about?” and generated two good questions. On the standardized test, students answered two comprehension questions for each of the four paragraphs. These tests assessed if training in question-generation would also affect traditional reading comprehension test performance (i.e., reading stories and then answering comprehension questions).

Students trained in question-generation showed significant gains on the standardized and criterion tests as compared to children who did not receive training. The fact that students improved in both question-generation and comprehension question answering may imply that training in questioning supported processes assumed to be related to question-generation, such as analysis of the text and search of important information (i.e., focusing on main ideas and important details and transforming these into questions). Because questions in this study were aimed at the literal level of reading comprehension, it is limited in terms of the effects of questions that are not exclusively literal such as inferential and evaluative ones. Nevertheless, this is preliminary evidence that students’ own questions on a narrative text can start as early as third grade and that this type of question instruction may improve students’ reading comprehension of short stories.

Question instruction based on story-structure. Another type of question instruction has been framed on the basis of a story-structure. Students were guided to ask questions following a unit or an element of a story. Based on a framework of story-schema instruction, a group of 11th - grade students were taught to derive story-specific questions from schema general questions while another group of students were told to use questions that had been posed by the teacher before reading the stories (Singer & Donlan, 1982).

Both types of questions, self-generated and teacher-generated, followed a problem-solving schema that characterized each story: plan, goal, action, obstacles, and outcomes that represented success or failure. Examples of schema-general questions were: (a) Who is the leading character? (b) What stands in the way of the leading character reaching his desired goal? Story-specific questions derived from these general questions were: (a) Is this story going to be more about the officer or the barber? (b) Will the officer be a willing victim? Students were taught how to generate story-specific questions from schema-general questions on six short stories that they also read in order to answer their own questions. Instruction was organized around five story elements that were also utilized to assess students in the outcome measures.

The group that received teacher-posed questions was asked story-specific questions such as: What do you think will happen to X? What will X do now? Why do you think that may happen? After each training session (twice a week for each group over three weeks, using six short stories), students in both groups had to answer a 10-item multiple choice quiz based on five elements of the short story: (1) the leading character, (2) the character's goals, (3) obstacles, (4) outcomes, and (5) the theme. The students who generated their own questions scored consistently higher on the quiz mean than the students who answered teacher-posed questions. Students tended to ask the highest number of questions for the story element taught in that particular session, revealing that instruction did impact the type of questions asked based on the story element taught.

Further evidence (Nolte & Singer, 1985) supports the use of students' knowledge of story structure in the generation of questions. In this case, younger students in grades 4 and 5, learned how to transform their story-grammar structures into story-specific questions by modeling appropriate questions generated by the teacher. Once again, students were taught to generate questions that centered on specific elements of the story. Results indicated that students who asked questions involving information that was central to the story content (i.e., following the modeled schema) improved their comprehension.

Instruction based on story structure has two important aspects when compared with instruction of questions at the literal level. One aspect has to do with the nature of the questions being taught, and the other with the contrasting impact of teacher-posed questions versus students' own questions. Questions in the first study (Cohen, 1983) referred to literal-type questions that students could find the answers to by looking for explicit information in the text. In contrast, in the latter studies, when questions were derived by following a story-schema, they demanded from the students some type of inferential thinking. This inferential thinking consists of students' effort to transform a schema-general question into a specific one. Not only that, but questions have to be framed in terms of the story's elements making students learn about the structure or schema of a story, and helping them to be story-focused and to be more specific in the types of questions asked. In the first study, "good questions" were described as starting with question words and answerable by information contained in the story, instructional features that seem to be more about surface features of questions (e.g., question words) than capturing content aspects of the story through the questions being asked (e.g., specific questions on story elements).

In terms of the contrast between teacher- posed questions and student-generated questions, the authors concluded that in the former case comprehension tends to narrow because students are likely to focus only on the passages related to the posed questions rather than on the overall text. It was inferred that these students assimilated less information than those students who learned to generate questions throughout the entire story (Singer & Donlan, 1982). Whether this is the case for all types of student-generated questions versus teacher-posed questions cannot be concluded from a single study. However, this study illustrated the need for differentiating impact of student-generated questions versus teacher-posed questions and the importance of highlighting the impact that students' own questions may have on the processing and understanding of text-material.

Question instruction based on text organization. In the same way that the emphasis of question instruction in the previous studies have focused on story structure, other instructional studies have had as their focal point for question-generation the organization of information in the text. Question types in these studies have been based on whether their answers are based on information available in the organization of the text or the prior knowledge of the reader. In Kintsch's (1998) terms, these questions were differentiated on the basis of whether information was derived from the textbase or from the situation model imposed on the text by the reader (Kintsch, 1998).

Under this type of instruction, third-grade students were taught to generate questions in peer-assisted sessions (Ezell, Kohler, Jarzynka, & Strain, 1992). Question types have followed the categorization of questions and answers by Raphael and Pearson (1985). Questions have been identified in relation to two primary sources of information: the text to which the question refers and the knowledge base of the reader (Pearson & Johnson, 1978; Raphael & Pearson, 1985). Three question types have been derived: (1) text explicit or "Right there" questions, for which the question and answer information is stated explicitly in a single sentence of the text; (2) text implicit or "Think and search" questions for which answer information must be integrated across paragraphs or sentences in the text; and (3) script implicit or "On my own" for which the answer is not found in the text and requires the reader to provide information from her own knowledge base. In their original study, Raphael and Pearson (1985) used this taxonomy and found that sixth-grade students who were taught these types of questions for expository texts, did, in fact, improve their awareness of the different types when asked to identify them. The students also improved the quality of their answers to the questions compared with students only taught to identify the different question types, not to generate questions themselves.

Using the same taxonomy of questions implemented by Raphael and Pearson (1985), Ezell et al. (1992) examined third graders' generation of questions as well as their answers. For these students, reading materials consisted mainly of third- grade basal readers and additional passages adapted from various reading-workbooks with narrative texts. The classroom teacher trained the students in both answering given questions and asking their own questions using the question taxonomy.

Throughout the study, students were asked to generate their own questions before answering questions given by project staff or teachers. This sequence was established to reduce the possibility that children would use the questions asked in the answering task if this preceded the question-generation task. Students would read for a pre-determined period and then they would work in dyads on worksheets that prompted them to ask three questions of a given type (i.e., one session included “Right there” questions, a second session “Putting it together” questions, and so on). Student performance on both asking and answering comprehension questions improved, however greater improvements were noticed in question-generation skills than in answering questions. In comparison to other third graders who did not receive the training, students also showed improvement on the reading comprehension measure of the California Achievement Test. This last finding suggested that learning to generate questions, and not only learning to answer given questions, has an impact on results obtained on a standardized comprehension test, a result that is interesting in the light that many instructional studies on question-generation do not concentrate on standardized measures. However, these results do not clearly show how different types of questions contribute to different levels of comprehension. Questions were rated as either correct or incorrect types, but no correspondence between a given question type and its relevance to the main theme in the reading passage was established. Nevertheless, it is highly probable that higher-level question types (i.e., “Putting it together”, “Author and you”, and “On your own”) will result in deeper processing of text because of the processes involved in answering them and thus, result in higher comprehension. Still, this trend is only speculative at this time and has not been empirically supported by the results in this study.

These studies revealed that different emphases on question instruction underscore different aspects and features of questions, and the types of comprehension they may support. In both types of instruction, questions derived from story-structure and text organization, text comprehension improved as a result of question instruction. Other efforts in question instruction, where the emphasis of questioning instruction has been on questions about the main idea of a narrative text, have resulted in increased awareness of main ideas and improved comprehension.

Question instruction based on main idea. With the goal of improving comprehension monitoring, eighth- and ninth-grade children with learning disabilities and sixth-grade children without learning disabilities were trained in self-questioning (Wong & Jones, 1982). Students were trained in the following tasks: (a) awareness of the rationale for studying this passage (i.e., Why are you studying this passage?); (b) finding and underlining the main idea(s)in the paragraph; (c) thinking of a question about the underlined main idea; and (d) learning the answers to their questions. Students were asked to apply the self-questioning technique to two passages containing five short-paragraphs. In the first passage, students were given prompt cards with steps and criteria for good questions. Good questions consisted of a paraphrased version of the main idea. For the second passage, the self-questioning steps were studied for a short period and prompts were removed. Students applied the steps learned to this passage and recorded their formulated questions. In both passages, the students received help only with decoding and vocabulary difficulties.

Learning-disabled (LD) students who were trained answered more comprehension questions correctly than untrained learning-disabled students. As well, LD students who received training in self-questioning to monitor their reading comprehension increased their awareness of main ideas in text. However, this difference was not found for normal-achieving sixth-graders when compared to other normal-achieving sixth-graders who did not receive training. The authors speculated that this may reflect that these students actively process reading materials most of the time and thus, the effects of the training were redundant. In their view, the fact that normal-achieving students did not benefit from training did not imply that they had mastered comprehension skills completely. Rather, all the normal-achieving students who used self-questioning may have already been familiar with it as a self-monitoring strategy. Thus, improvement in main idea self-generated questions as a result of training was not noticeable for these students.

Even though in this case self-generated questions on the main idea appeared not to have increased normal-achieving students' awareness of it, other evidence (Palincsar & Brown, 1984) has shown that middle school normal-achieving children improved in asking main idea questions as a result of instruction. Additionally, these children improved their comprehension on a range of expository passages.

When considering the different types of questioning instruction for narrative texts, the majority of the interventions support the positive impact of student- generated questions on reading comprehension and understanding of the text. However, to distinguish the advantages of one particular type of instruction over another, or whether any question type can support comprehension better, is difficult. Attempts have been made to examine different studies on questioning instruction that compare their effect sizes in terms of different question features (Rosenshine, Meister, & Chapman, 1996).

Consistent results have been found for differences across studies in terms of some question features such as question prompts. I turn to a review of these studies next.

Question instruction based on question prompts. A meta-analysis of instructional studies of student-generated questions revealed valuable results in terms of comparing different types of instruction on question-generation (Rosenshine, Meister, & Chapman, 1996). Studies were grouped according to the types of question prompts that were used to teach question-generation. The authors categorized type of question instruction according to five prompt types. Question prompts were: (a) signal words -students were taught to use signal words such as *who, where, how, why,* etc. to start questions, (b) generic questions and generic question stems -students were taught to derive specific questions from generic question questions such as: How are X and Y alike? What are the strengths and weaknesses of X? How is X related to Y? What conclusions can be drawn from X? (c) main idea -students were taught to identify the main idea of a passage and use this to generate questions, (d) question types -this procedural prompt was based on the work of Raphael and Pearson (1985) and followed their QAR categories in which each type of question is based on a particular relationship between the question and its answer (e.g., a question whose answer can be found across sentences), and (e) story grammar categories -in these studies (previously reviewed) story grammar or story structure elements were utilized as the basis to teach question-generation (e.g., main character or character's goals as a basis for question-generation).

Among other criteria, evaluation of these studies consisted of whether reading comprehension was assessed in them and the type of comprehension tests utilized. Results were presented separately for standardized and for experimenter-developed reading comprehension tests. Overall, instruction in question-generation during reading yielded larger effect sizes for experimenter-based comprehension tests (effect size = .87) than for standardized tests (effect size = .36) when these were utilized as outcome measures assessing the impact of questioning instruction on comprehension.

Analyses by question prompts revealed that those studies that utilized signal words, generic question stems, and story grammar categories were the most effective in terms of the impact of questioning instruction on comprehension tests. In particular, all seven studies for which instruction was based on signal words and used experimenter-developed comprehension tests obtained significant results (these studies were for grades 3 to 8). Additionally, in almost all studies that used experimenter-developed comprehension tests and that provided students with generic questions or question stems, significant results were obtained. This question prompt was successfully used with students ranging from sixth grade to college level. Based on these results, it was concluded that signal words and question stems from which specific questions can be modeled were the most concrete and easy-to-use prompts for teaching question-generation.

Conversely, only two of five studies that had students using the main idea of a passage to develop questions obtained significant results for one of the ability groups in each study. In studies for which students were taught to use question types (based on the categories of text explicit, text implicit, and schema-based questions by Raphael & Pearson, 1985), results were not significant in all three studies that used standardized reading comprehension tests. Results were confounded for the only study that utilized reading comprehension, experimenter-developed tests for this question prompt.

This meta-analysis included studies of students of different ages, elementary school to college level, revealing that signal words, question stems, and story grammar categories are functional units of instruction for question-generation across age and genre. However, an interesting point mentioned by the authors, is that none of the authors of any of the studies provided a theory or a rationale to justify the use of specific question prompts. Therefore, although evident for many researchers that a reading strategy such as questioning must play a role in reading comprehension, there seems to be an absence of a theoretical argument that supports or attempts to explain the association of question-generation and reading comprehension. This, in turn, has direct consequences for the absence of suggestions of pedagogical tools that can be used to teach this strategy.

Despite this and other limitations, this meta-analysis and most of the narrative studies reviewed in this section, purport instructional frameworks that attempt to differentiate the impact that different types of questioning instruction may have on reading comprehension. Such types of instruction may constitute the first endeavors in understanding the potential relationships that may exist between questioning and reading comprehension.

Expository texts

As with narrative texts, the role of student-generated questions for expository texts has been mostly revealed through the impact that instructional interventions have had on reading comprehension. Some authors have noted that research on student-generated questions and prose processing is meager and sometimes contradictory (Davey & MacBride, 1986). Others (e.g., Dillon, 1990) have emphasized limitations for instructional research per se, observing that often the results of instructional studies in question-generation are difficult to interpret. Frequently this is due to poor specification of outcome variables and other methodological shortcomings such as lack of comparison groups (see Wong, 1985 for a review). One limitation encountered in some instructional studies of questioning for expository texts is the lack of discrimination of questioning among other intervention variables (e.g., other reading strategies). On other occasions, research has failed to discriminate among the effects that different types of questions have on different processes of comprehension, either because comprehension outcome measures have been poorly identified or because question types have not been specific. The different studies on students' questions in relation to expository texts are examined in view of some of these factors in the following subsections.

Questioning within multiple strategy programs. Different from the studies in questioning for narrative text, the focus in studies for expository texts has not always been on self-generated questions as a main variable of interest. Rather, questioning has often been secondary to other variables that interact with student questioning. These variables can be classroom environment, instructional techniques, or individual learner's factors such as prior knowledge. However, for other studies about expository text, questioning has become the focal point of inquiry. For these studies, inferences in terms of comprehension or knowledge gains as a result of question instruction is more discernible.

Among different instructional techniques, some researchers have examined students' questions in the context of peer or reciprocal teaching. One such study examined seventh-grade students' questions in the context of multiple strategy training (Palincsar and Brown, 1984). Instruction included summarizing, clarifying, and predicting. Using reciprocal teaching with a tutor, the students took turns leading a dialogue centered on features of expository texts that represented a range of topics from social studies to science. Six students participated in this training. Each strategy was separately taught, but not practiced, as an isolated activity. Rather each strategy was taught as part of the whole interactive training. Questioning was one of the strategies taught. Training in questioning involved asking questions on the main ideas of the paragraphs presented, rather than on details. Students were taught how to form questions properly (*Why* questions, for example), and instructed to focus on what would be good main idea questions that teachers may possibly generate. Students were asked to write "10 questions a classroom teacher may ask if testing the students' knowledge of the students" (Palincsar & Brown, 1984, p.134). Questions had to focus on the main ideas of the paragraphs and had to be framed in one's own words, rather than repetitions of words occurring in the text.

Due to the interactive nature of reciprocal teaching, students' questions became more like the tutor's questions as the training progressed. These questions requested information about the gist of the paragraphs in the students' own words, rather than early forms of questions that would take verbatim information from the text and append a question inflection at the end of them.

Students' questions were rated by independent judges in the following way: a main idea question (worth two points), a detail question (one point), a question lifted from text (zero points) or paraphrased (one point). Questions were also rated on their quality on a 5-point scale ranging from *very poor* to *excellent* (with the most clear and complete questions rated as highest, although no further details as to what constituted highly-rated questions were provided). Additionally, if a rater indicated that a question would be asked by her, the question got an extra point. This emphasized the higher level attributed to "teacher-like" questions.

Students improved in the strategies taught during reciprocal teaching. They were able to write better summaries and improved in reading comprehension as a result of training. Students' reading comprehension was measured by criterion-referenced measures such as the level set by average seventh-grade readers. As it pertains to questions, students asked more main idea questions in their own words than detail questions after participating in reciprocal teaching. Posttest measures assessed whether students could predict questions a teacher may ask in reference to a text segment. Students in the reciprocal teaching training were not better at predicting "teacher-like" questions than the average seventh-grade comprehender.

A limitation of this study is that it does not distinguish the real impact of question-training or its association with reading comprehension. This is due to the fact that questioning was part of a larger set of strategies taught in the context of reciprocal teaching. This has made the impact of questioning itself difficult to determine mainly because of the lack of isolation of questioning in relation to other cognitive strategies and instructional factors. Had strategies been examined in terms of their specific contribution to comprehension, a better description of the impact of self-generated questions for these students would be possible.

Within the expository genre there have been other studies that have taught questioning as a component of multiple strategy training. For instance, Taylor and Frye (1992) had fifth- and sixth-grade teachers instruct students of average reading ability to generate questions in reference to social studies textbooks. These students also received instruction in comprehension monitoring, reciprocal teaching, and summarizing. For four months, students received weekly instruction on all four strategies. In relation to questioning, students were asked to write six important questions in reference to material contained in three to four pages of social studies textbooks. Little information was provided on the specifics of the questions students were to write. Students who received the multiple strategy training improved in summarizing, however there were no differences between trained and non-trained students in their ability to self-generate questions on the social studies material that they read. Once again, it seems that the impact of self-generated questions appears to be mingled or confounded by the effects of the other strategies and thus, links between student questions and comprehension are difficult to make.

Instruction of literal and inferential questions. In studies where student-generated questions are one element in a multi-strategy instructional approach, question effects are difficult to determine among the effects of other strategies. However, some researchers have isolated students' questions as the only variable influencing reading comprehension of expository text (e.g., Mac Gregor, 1988; King & Rosenshine, 1993). These researchers have either emphasized a few types of questions taught to students, or they have emphasized the instruction of question forms or the syntactic aspects of questions. On other occasions, the emphasis has been on the types of content the questions asked.

Instruction through a computerized text system (CTS) where questions are taught within an explicit framework was implemented with third-grade students (MacGregor, 1988). For these students, questioning was taught as a strategy used to clarify information and focus attention on a text in a computer program. Students were taught to generate specific kinds of questions on a text system based on a computer model. Two types of questions were used; clarification questions and focus of attention questions. Clarification questions were those questions that were asked to elicit definitions of words in the passages. Focus of attention questions were literal text-derived questions (e.g., Who sat in the chair? What did the girl eat?). Students were presented with passages consisting of four to six paragraphs of expository text, with one paragraph presented on the screen at a time. Students could request definitions (clarification questions) for as many words as they needed.

Focus of attention questions consisted of literal-level *who, what, when, where,* and *why* questions that could be answered by the text on the screen. Examples of appropriate questions were modeled at the end of each paragraph. If the student's question was appropriate, the answer was highlighted in the text on the screen. An inappropriate question emitted a response that referred the student back to the paragraph and allowed the student to ask another question or have an appropriate question modeled by the system.

Students were assessed on whether they asked both kinds of questions (clarification and focus of attention questions) or just one kind of question. Students who asked both types did not differ significantly in vocabulary and comprehension from students who asked mainly one question type. Thus, there were no statistically significant differences between these groups in vocabulary and reading comprehension as a result of type of questions asked. Additionally, a significant positive correlation was found between the number of inappropriate questions asked and gains in comprehension.

Inappropriate questions consisted of omission of question words, incorrect grammar or spelling, and questions not answerable by the text.

An explanation for the positive correlation between number of inappropriate questions and improved comprehension can be given in terms of the impact that re-reading may have on comprehension. In other words, when asking questions that received negative feedback from the system (i.e., inappropriate questions), students were directed to re-read the text and formulate another question. Re-reading the text may have caused students to be more attentive to the text and thus, lead them to better comprehension.

An alternative explanation for the correlation between inappropriate questions and comprehension may be attributable to the constraints the system imposed on the types of questions to be asked. That is, according to the results, students' questions increased in the number of questions asked, but students did not improve in their ability to ask questions. Being restricted to asking only definitional and literal level questions may preclude students from deeper processing of text. The need for question types that transcend the literal level and promote knowledge integration may be the key to higher text comprehension.

This latter study emphasized the role of self-generated questions and their impact on comprehension unlike the previous studies in which student-generated questions were not differentiated as a specific variable. However, limiting the types of questions taught to literal and definitional ones only, may also limit reading comprehension, rather than foster other components of comprehension such as integration of knowledge and inferential thinking.

Within the expository genre, other studies have examined the impact that other-than-literal types of questions have on text comprehension. Questions on the main ideas of a text selection have also been the focus of instruction for expository texts. Sixth-grade students have been taught to formulate questions on the main ideas of expository paragraphs (Dreher & Gambrell, 1985). Their comprehension was assessed when they were instructed to formulate questions and when they received no instruction to do so. Question instruction specifically consisted of: (a) finding the main idea of each paragraph; (b) generating a question about each main idea; and (c) learning the answers to students' own questions. Appropriate questions had to elicit the main idea as an answer. For the purpose of this study, all paragraphs had explicit main ideas. Three groups participated in this study. Training was provided to one group only. Another group of students was taught to formulate a question on each paragraph –and to learn the answer, but received no training on generation of main idea questions. A third group of students was taught to read, recite, and review the passages in order to learn them. Instruction was given on two sessions in which students received detailed explanations and had ample time for guided practice.

After instruction, all students were given two separate comprehension tests. One test came after four days of instruction and the second one was administered after nine days from the last instructional session. Tests consisted of passages taken from social studies and science. In the first comprehension test, students were asked to study the expository passages and were specifically told to use the technique they had been taught. Instructions on the technique appeared on top of the passages. In the second test, students were told to study the passages with no specific instructions on how to do so. On both occasions, after studying the passages, students were required to construct their own responses to the main idea and detail questions. Responses were scored by comparison to an answer key.

Analyses were conducted for each of the two testing sessions separately. For the first comprehension test (administered four days after last lesson) students in all three groups did significantly better on detail questions than on main idea questions. Additionally, there were not significant differences in mean percentage of correct responses to comprehension questions on the first comprehension test as a function of training. There were not statistically significant effects as a result of type of instruction on performance on the second comprehension test either. However, on the second test, students who received instruction on question-generation did better on the main idea questions than on detail questions. There was no difference of performance on question type for the other two groups. Even though results were not equally good across testing situations for the students who received question instruction, (i.e., these were significantly better only for the last testing session), these results still support the impact of question instruction on understanding of main idea. That is, students who were taught to generate main idea questions on an expository paragraph could answer instructor-provided main idea questions significantly better than detail questions on a *new* paragraph -and after nine days of instruction- in comparison to students who did not receive this type of question instruction. Therefore, it seems that the impact of instruction on main idea questions is positive for reading comprehension, not only with different and new texts, but also over time.

Aside from main idea questions, investigators have also studied inferential questions, “thought-provoking” questions or integrative questions (e.g., King & Rosenshine, 1993), and “research” questions (Cuccio-Schirripa & Steiner, 2000) to learn if any of these questions implied deep processing of text in contrast to literal types of questions whose answers requested only explicit information from text.

Some investigators (Davey & McBride, 1986) have combined both literal and inferential types of questions in their instruction. They instructed sixth graders in question-generation for expository passages. The impact of this instruction was examined on the basis of the quality and form of the questions generated, as well as the accuracy of the responses to post-passage comprehension questions.

Five experimental groups participated in this study. One group of students received instruction in question-generation. Three groups engaged in question practice (both literal and inference types of questions) and there was a control group. All groups met for five 40-minute lessons over a two-week period.

Students who received question instruction were taught to generate two types of inferential questions: those linking information across sentences and those tapping the most important information. Students were taught to discriminate between inferential (think) and literal (locate in the text) types of questions. They were specifically taught to generate question stems for linking information across sentences and across passages, to use signal words to generate questions on main ideas, and how to respond to questions that required relating information. A rationale for good think-type questions, after reading a passage, was also introduced: they helped to remember key information, to know if one needed to reread and to anticipate test-questions. Checklists and self-evaluation measures covering the steps taught were also part of the training.

Two groups that engaged only in question practice had to answer four free-response questions after reading three passages. One group answered only inferential questions and the other group answered only literal questions. The third group that engaged in question practice had to generate two main idea questions on the same passage that the other groups had read. Students in this third group were explicitly told that main-idea questions had to make them think about what they read and could not be answered by underlining parts of the passage. Unlike the group that received instruction on question-generation, this group only received this basic information on main-idea questions. In the control group, students did not participate in any question related activity, but they completed a vocabulary activity instead.

All four groups of students were assessed by their reading of two expository passages in two testing sessions. For each passage, students had to generate two good think-type of questions that tapped the central information in the text. Students also had to answer four inferential and four literal questions for each passage.

Student-generated questions were dichotomously scored for their quality as correct or incorrect. If the response required central ideas, the gist of the text, or the integration of information across sentences, they were scored as correct. A question was scored as incorrect if its response led to a restatement of text information or if it required evaluation and application of passage information based on the reader's attitudes, prior knowledge, or both. Question form was evaluated according to the use of question words and whether the question required more than a *yes* or *no* response. Student responses to passage questions were also assessed. A key of textually derived responses created for each question was used.

In terms of responses to their questions, both the trained students and those in the question practice groups did significantly better than the control group students. However, those students who received explicit training in question-generation and question response to inferential questions outperformed all of the other groups. Additionally, students who received training in literal question types and were engaged in the practice of these questions also did significantly better than the control and inference practice groups.

Regarding generation of questions, the students who received explicit question training asked higher quality questions than the rest of the students. The trained students did better than the comparison groups -except for the inference-practice group on question form assessed by the use of question words and by questions requiring more than a yes/no response.

These results support the positive impact that instruction in question-generation has on the types of questions asked as well as on reading comprehension responses to questions. As it refers to responses to questions, the benefits of instruction and practice were clear for students taught inferential and literal types of questions. However, those students who received instruction in question-generation and question responses to inferential questions did significantly better than the rest of the groups. This emphasizes the importance of explicit instruction (rather than just practice) on these types of questions. These results led to speculation that one mediating process for inferential question-generation may be active text processing, a process that requires attention to important information in text elicited by asking inference-type questions (Davey & McBride, 1986). Taking into consideration that students trained in question-generation did significantly better not only on inferential but also on literal post-passage comprehension items than non-trained students, it is probable that the authors' view is warranted. In other words, it is plausible that the generation of the higher order type of questions (here "correct" or inferential questions) led to a more thorough processing of text, which resulted in a better performance on responses to literal questions even if these were not emphasized during training.

Furthermore, together with active or deeper processing of text, students' inferential questioning may also foster students' focus and attention on other aspects of text such as text macrostructure. As previously discussed, it appears that question-generation involves a series of mediating processes that may result in higher-order thinking and deeper text processing. The results in the previous study support this point, as well as emphasize that deeper text processing is better supported by inferential or higher-level questions.

The studies reviewed so far in this subsection underscore some of the positive impact that different question types, such as literal-information or text-based versus inferential or main idea questions, may have on comprehension processes of expository texts. In the following subsection, question types are examined in reference to studies that deal with one particular type of expository text, that of science knowledge for elementary and middle school children.

The Role of Questions in the Science Inquiry Process

Researchers who looked at the role of questions in the science inquiry process (e.g., Scardamalia and Bereiter, 1992; Cuccio-Schirripa and Steiner, 2000) have examined variables that may have an impact on student questioning as well as science knowledge construction. These variables have included science processes and procedures of inquiry. A study by Scardamalia and Bereiter (1992) investigated fifth and sixth grade students' questions on science topics. Two types of questions were examined: text-based and knowledge-based questions.

Text-based questions were prompted by a text preceding the questions and were generally about the text. Students were instructed to ask questions on the topic of endangered species after some preliminary material about the topic had been presented. Knowledge-based questions had to spring from the child's interest or from an effort to make sense of the world (i.e., the child's *own* question). Students in this group were asked to write questions reflecting what they wondered or wanted to know about endangered species. They were told not to be concerned about whether they could answer the question or not. The source of these questions would stem from a gap or discrepancy in the child's knowledge of the topic. The authors proposed that the two kinds of questions imply differences in the extent to which students can direct the learning process.

Text-based questions were elicited after some introductory lessons, videotapes, and exposure to reference material. For the knowledge-based questions, students were presented with the topic and went directly into generating questions.

Student-generated questions were scored according to four categories:

1. Contribution of the answer to the question to students' understanding. A 4-point scale rated questions according to: (a) *no contribution*, (b) *minor addition to knowledge*, (c) *significant addition to knowledge*, and (d) *conceptual understanding*.

2. Fact/Explanation. A 4-point scale rated questions on whether the question implied *a rather trivial fact* or at the highest level, the search *for a causal explanation.*

3. Interest. A 4-point scale that ranged from *no interest*to *high interest*. It assessed raters' interest in pursuing answers to students' questions.

4. Complexity of Search. A 4-point scale that varied in complexity of the search process. The scale ranged from *no need to search for the answer* (since this was already known to the questioner) (Level 1) to *having to search for an answer that would require integration of complex and possibly divergent information from multiple reference sources* at the highest level (Level 4).

Questions generated under the knowledge-based condition (i.e., the child wondering about the topic before reading about it) received the highest ratings on all four scales. These questions were judged to be significantly superior in their potential contribution to knowledge, in their focus on explanations instead of facts, in requiring more complex information searches, and in being more interesting to the raters.

However, from this preliminary study it was not clear what may have been some of the prerequisites or individual differences that may promote knowledge-based questions. Thus, based on prior evidence (Miyake & Norman, 1979) a follow-up study investigated whether knowledge-based questions required substantial prior knowledge in order to be generated.

In this second study, Scardamalia and Bereiter (1992) found that knowledge-based questions included two subtypes. One question type consisted of basic information. These questions were directly targeted at the kinds of information available in textbook or encyclopedia treatment of a topic (e.g., What are fossil fuels? What are fossil fuels made of? Where do they come from? What are the different types?). These questions seemed to seek orientation to a topic. The second type of questions were "wonderment" questions. They reflected curiosity or a knowledge-based speculation, in contrast to looking for basic information (e.g., Can you make different fossil fuels by mixing other fossil fuels? Are fossil fuels still being explored by scientists? Is there anything that will only run with fossil fuels?). These questions appeared to show "active thinking in which what is already known is used to probe beyond the basics of the topic" (Scardamalia & Bereiter, 1992, p.188). Children tended to ask basic questions when they were not familiar with the topic at hand and they asked more "wonderment" types of questions when they had some exposure to the topic.

Taken together, the findings in these two studies revealed that when children asked questions in advance of studying a unit, they adjusted the kinds of questions they asked according to their level of knowledge. If they already had a basic understanding of the topic, they asked questions that had the potential to extend their conceptual understanding. If they lacked elementary knowledge, they tended to ask questions of the basic type to seek introduction or guidance to a topic.

Studies such as those just described have been conducted by researchers looking for instructional techniques and questions that foster conceptual knowledge in science. There have been other attempts to foster conceptual knowledge in science through the use of students' questions. In one of those studies (Cuccio-Schirripa & Steiner, 2000), high-level questions in science were defined in relation to the science inquiry process. High-level questions were defined as "researchable" questions. In a science context, this meant framing meaningful problems. Seventh-graders had to identify and construct meaningful problems through demonstrations, the use of magazine articles, field trips, and science textbooks (Pizzini, Shephardson, & Abell, 1989). Meaningful problems or researchable questions should also lead to a deeper understanding of science concepts. Two groups participated in this study. One group received instruction on researchable questions and the other group did not receive questioning instruction.

Instruction on researchable questions consisted of an introduction highlighting the importance of questioning in learning and research, and a definition of researchable questions. These questions for which answers are often unknown, require exploration, investigation, and experimentation. They often require data, collected with variables that are measured, specific, and manipulated. To provide some practice, examples and non-examples of researchable questions were provided. Students were later asked to identify from a list of 109 questions those that were researchable and those that were not. In addition, students had to write a total of four questions on four different science topics. Students were previously asked to rate two of the topics as high-interest and two of the topics as low-interest. Two of the students' questions were in reference to the low-interest topics and two questions were about the high-interest topics. Questions were rated on a hierarchical scale of 1 to 4. The scale is presented next.

Level 1: Questions require factual information or simple yes/no responses. For example, memorized statements such as: How many meters deep is Lettuce Lake?

Level 2: Questions require an explanation or description such as a classification or a comparison. For example: How are oak trees different from pine trees?

Level 3: Questions represent cause-effect relationships but some variables are not specific or measurable. For example: What is the effect of air on the bounce of a ball?

Level 4: Questions also represent cause-effect but variables are very specific, measurable, and manipulable. For example: To what degree does the volume of the air inside a ball influence the number of times a basketball will bounce?

When students received question instruction the sum of the means of high and low interest level questions were significantly higher than the means of students who were not exposed to questioning instruction. However, although students' questions were improved as a result of instruction, the authors did not specify in what direction questions were improved (i.e., it is not known whether students asked more Level 4 questions or not). The authors proposed that the whole process of developing a researchable question may result in higher-order thinking. "While students are formulating researchable questions, they may be elaborating, making more connections, integrating prior knowledge, and retaining more facts" (Cuccio-Schirripa & Steiner, 2000, p.221). The difference between levels of questions for high and low interest topics was analyzed as a function of instruction, reading achievement, and two other variables-math achievement and science achievement. No significant differences in question levels were found as a function of any of these variables when these were simultaneously analyzed.

In a related study, question types were characterized not only in terms of the type of knowledge contained in the answer but also in terms of question stems. Such is the case of the question instruction provided to fifth-grade students who were taught question stems and “thought-provoking” questions in relation to science texts (King & Rosenshine, 1993). “Thought-provoking” questions were defined as questions that elicited responses such as explanations of concepts or relationships, inferences, justifications, drawing conclusions, and application of information to new situations. A group of students were taught to generate questions based on a series of structured question stems. Another group of fifth graders was taught to generate thought provoking questions based on signal words only. A third group was encouraged to ask and respond to each other’s questions but no specific instruction was provided. Examples of questions taught based on question stems were: How is X important? How does X affect Y? How are X and Y similar? How are X and Y different? What do you think would happen if X…? Why is Y better than X? Students who were taught to generate questions based on question words (e.g., *how, why, where, when* etc.) were taught question words and examples of questions using them. Even though it was stressed that these questions should be thought- provoking rather than just literal ones, question words were the only prompt provided for these students.

Instruction occurred within cognitive modeling and sufficient scaffolded practice in question-generation with corrective feedback. The purpose of question asking and answering was explained to students in terms of better recall and understanding of the material presented in science lessons.

Students were compared in terms of reading comprehension, frequency and types of questions generated, and knowledge representation. Reading comprehension was assessed using tests with multiple-choice and open-ended items. Items of both formats called for literal comprehension as well as for explanations and inferencing beyond the text material (e.g., a multiple choice item could be: Which of the following animals would be most closely related to a shrimp? (a) snail, (b) sea anemone, (c) spider). An open-ended item could be, "Explain how the animals in the tide-pool become exposed to the elements". Students' questions were coded according to five categories: (1) total number of questions, (2) fact questions, (3) definition questions, (4) integration questions (linking ideas or concepts in some way, such as similarities and differences), and (5) explanations. Lastly, students' knowledge representations were assessed using knowledge mapping or concept maps. Students' knowledge maps of the unit on tide pools were analyzed in terms of accuracy, completeness, and comprehension of the material, as well as for integration of prior knowledge. Maps were rated on a scale from 1 to 5 according to these criteria in reference to a teacher- constructed knowledge map.

Results showed that students who were taught question-generation by using highly elaborated stems were better at retaining literal information from the science passages after a short period of time. Also, students taught with question stems were better at making inferences and retained this information better than students taught questions using signal words and better than students not exposed to question instruction. In terms of the number of questions asked, students taught with highly elaborated stems asked more integration questions and engaged in more science explanations than did students in the other two groups. Additionally, instruction in highly elaborated stems helped students ask more integration questions later in an unprompted context. However, students taught to use signal words tended to ask only more factual and definitional questions, rather than inferential ones, when unprompted in a different context.

With regard to knowledge representations, students who used highly elaborate stems also generated more complete knowledge maps than students in the other two conditions. This showed that their knowledge representations of the science topics were more complete than those of their peers who were not exposed to the same type of questioning instruction.

Overall, results of this study are valuable for several reasons. First, they underscore the benefits of structured question instruction. Students taught to formulate questions using elaborate question stems showed better performance on reading comprehension, knowledge mapping, and the number and type of questions asked (i.e., inferential rather than literal ones) in a new unprompted context than students who did not receive such instruction. Secondly, these results support evidence for a specific type of structured instruction, that of using question stems to elicit specific knowledge processes, in this case, explanations (e.g., Explain why… What does…mean?) and inferential thinking (e.g., What is a new example of…? What do you think would happen if…?). Furthermore, explanations and inferences may subsume still other cognitive processes such as comparing and contrasting, defining, explaining, and justifying, all of which were engendered by posing questions based on the question stems provided. It seems that questions that favor these processes are a result of structured instruction that taps into questioning as a cognitive strategy. This type of structured instruction on questions provides explicit guidance on the types of questions to be asked and fosters students' awareness of asking "thought-provoking" versus merely literal questions. Question instruction that supports specific kinds of connections among ideas (i.e., compare and contrast, classification, cause and effect, etc.) so as to build highly elaborate knowledge representations, such as conceptual knowledge in science, may be needed by students during elementary and middle school.

These four last studies (Scardamalia & Bereiter, 1992; Cuccio-Schirripa & Steiner, 2000, King & Rosenshine, 1992) represent noteworthy contributions on question features that may guide students' understandings and building of conceptual knowledge in science. Not only do they offer question types that have been related to types of learning, but some have also highlighted the importance of variables associated with students' questions such as prior knowledge. Additionally, these studies underscore the importance of teaching the use of different question types both for the development of an inquisitive attitude in students and because of the cognitive benefits they have for reading comprehension and science learning.

Impact of Prior Knowledge on Question Types

Within the expository genre, and science inquiry in particular, several researchers have pointed to the impact of prior knowledge on the types and number of questions asked (e.g., Miyake & Norman, 1979; Scardamalia & Bereiter, 1982; van der Meij, 1990). Some of this research has explained that impact by characterizing questions that require the integration of prior knowledge with text information as high quality questions. High quality questions have been described with slight different emphases in different studies. As seen in the previous section, in some studies high quality questions were characterized by probing what was known about a science topic (Scardamalia & Bereiter, 1992). Other researchers have defined high-level questions as requiring a causal explanation of natural phenomena (Costa, Caldeira, Gallastegui, & Otero, 2000).

In this latter study, students in 8th, 10th, and 12th grade generated questions on scientific texts explaining natural phenomena after reading two science paragraphs (Costa, Caldeira, Gallastegui, & Otero, 2000). Students were prompted to ask questions on everything they did not understand in the text and their questions were evaluated in terms of their quantity and quality. Quality of the questions was assessed using Graesser et al's taxonomy (Graesser, Person, and Huber, 1992; Graesser & Person, 1994). Within this taxonomy questions categorized as "Deep Reasoning Questions" (DRQ) can consist of causal antecedents and causal consequences among other categories. Students asked mainly two types of questions: low-level questions and high-level questions. Low-level questions consisted of word or term definitions and were found across all three grades. Students also asked high-quality questions which were characterized as revealing clear inconsistencies between the reader's prior knowledge and the text information or inferences drawn from text, for instance: "The text says that clouds have a characteristic white color. Why is it that clouds are darker sometimes?" These types of questions were considered high quality because they educed the integration of text-information with prior knowledge.

Among different types of high-quality questions, causal antecedent questions were the ones most frequently asked. Examples of causal antecedent questions were: "Why does it rain sometimes more often than other times?" or "Why are these gases soluble in water?” As noted by the authors, higher incidence of causal antecedent questions in reference to scientific texts reveals that students are trying to understand why certain events occur. However, the authors observed that when students had difficulty understanding the terminology in the text they tended to ask more definitional or term questions than causal questions. In this sense, these results agree with those from Scardamalia and Bereiter (1992) in which elementary school students tended to ask more definitional types of questions when they did not know enough about a topic, but were able to ask more high-level questions (knowledge-based questions) when they had some prior knowledge on the topic.

It appears then that if the questioner has difficulty understanding the terminology in the text, questions may tend to focus more on word meanings, preventing students from addressing questions to the causal relation or any other type of high conceptual knowledge. In other words, high-quality questions tend to be asked most frequently when students can focus less on text terminology and more on text content and, thus, can integrate their prior knowledge into their questions.

Similar results were found for eighth-grade students who generated questions in different knowledge conditions (Graesser, Langston, & Bagget, 1993). Students were assigned to two knowledge conditions: A deep-knowledge condition in which students had to design a woodwind instrument following certain criteria versus a simpler task where instructions were to assemble a band for a party. Students asked taxonomic (e.g., categorization of instruments) and definitional questions in a substantial number when they started designing the woodwind instruments (i.e., deep knowledge condition). They also asked classification questions when assembling the band, a more superficial task that did not require deep knowledge. Causal questions, on the other hand, were asked more frequently in the more demanding knowledge condition (deep knowledge) which required more elaboration and familiarization with the topic at hand.

Evidence throughout these studies appears to support the notion that prior knowledge in a given topic or domain has some influence on the type or quality of the questions asked by students in that topic or domain. Students with basic prior knowledge on a topic tend to ask questions at a definitional or taxonomic level (i.e., questions that will provide a general orientation to the topic). However, students with higher prior knowledge of a topic will tend to ask causal and other types of explanation questions. This may be due to the fact that students' prior knowledge informs their questions. Therefore, informed questions will not just focus on understanding the elements of a topic (i.e., definitions) but rather on the interaction of these elements (i.e., explanation or causal questions).

Prior knowledge appears not only to influence type of questions but also the number of questions students ask (Miyake & Norman, 1979; van der Meij, 1990). One of the first studies to focus on this aspect found that college students who had high or low prior knowledge tended to ask fewer questions than those students whose prior knowledge was average (Miyake & Norman, 1979). These authors suggested that students who had low prior knowledge were unable to cope with material that went beyond their present knowledge and did not have the framework for asking questions. On the other hand, students with high prior knowledge asked only a few questions on easy material because they probably had most of the information that they would need, leaving the students with average prior knowledge asking the highest number of questions.

Number of questions in relation to prior knowledge has also been investigated for elementary school students. Fifth-graders with little prior knowledge and much prior knowledge selected and generated questions based on a model (van der Meij, 1990). Students had to generate global (i.e., general) and specific questions on word meanings. Global questionsconsisted of requests for global hints and specific questions requested specific hints on word meanings. It was found that students with little prior knowledge tended to ask significantly more global than specific questions than students with higher prior knowledge.

Throughout these studies evidence highlights that prior knowledge affects the quality and sometimes also the number of questions asked. It appears that asking good or high-level questions may be partially dependent on domain or topic knowledge in order for those questions to lead to conceptual, well structured knowledge (Scardamalia & Bereiter, 1992).

Contributions and Limitations of Research in Questioning for Narrative and Expository Texts

Research in questioning for both narrative and expository texts has attempted to improve reading comprehension or learning of a particular content or process (such as inquiry science) by focusing on question instruction. The fact that most of these studies were instructional ones, assumes a relationship between the role of questions for reading comprehension and for knowledge construction: Students who ask questions in reference to a text can improve their comprehension or knowledge of that text as a result of learning to generate questions in relation to that text.

The nature of question instruction in these studies has varied widely within and across genres, with question types ranging from those based on story structures or text organization for narrative texts, to inferential and thought-provoking questions for certain types of expository texts such as inquiry science texts. Furthermore, not only questioning instruction has been characterized by a diversity of question types, but many investigators have agreed on the positive impact that inferential, thought-provoking or explanation-seeking questions have on knowledge processing and reading comprehension (e.g., Davey et al., 1986; Ezell et al., 1992; Graesser et al., 1985; Scardamalia et al., 1992, Cuccio- Schirripa & Steiner, 2000). Many of these researchers have considered these questions "higher-level" because of the roles that they may play in improving reading comprehension and in deeper text processing.

However, while previous studies have used questioning in reference to text as a way to improve reading comprehension and have distinguished among question types, they have not assessed how content complexity of questions can be related to levels of text comprehension. In other words, the literature in student questioning has not categorized questions into a hierarchy of conceptual complexity that can be associated with degree of conceptual knowledge built from text. A way to categorize questions in terms of their conceptual complexity is to classify them into levels that represent degrees of conceptual knowledge. Questions that are categorized into levels that imply degrees or levels of knowledge are, by definition, organized into a graded series. Thus, it will be appropriate to call such a categorization a hierarchy of questions.

In this study, a high degree of conceptual knowledge is defined by breadth and depth (e.g., Chi, de Leeuw, & Lavancher, 1994; Alao & Guthrie, 1999), where breadth implies knowledge of concepts within a given domain and depth is characterized by knowledge of relationships among those concepts. High-level questions within a question hierarchy will consist of requests for such type of knowledge. This relationship between questions in relation to text and reading comprehension has been absent from the literature in student questioning. Previous studies have not proposed a theory of questioning that attempts to describe text-referenced students' questions in terms of their conceptual complexity and the association of questions with degree of conceptual knowledge built from text.

Question Hierarchies for Narrative Texts and for Science Inquiry

In the research literature in questioning, there is the need for a question hierarchy that captures question content complexity. Some investigators (e.g., Graesser, Person, & Huber,1992; Cuccio- Schirripa & Steiner, 2000) have proposed question hierarchies that have made major contributions to the characterization of students' questions in different domains. In this section, I concentrate on two such hierarchies: (1) the question taxonomy developed by Graesser, Person and Huber (1992) for narrative texts and (2) the *Middle School Students' Science Question Scale* developed for categorizing students' questions in science by Cuccio- Schirripa and Steiner (2000). Even though both question hierarchies have been briefly reviewed previously, a more detailed presentation is pertinent here. These question hierarchies serve as research antecedents for the hierarchy for ecological science to be presented and used in this dissertation.

In the hierarchy developed by Graesser et al. (1992), a question is defined as an expression in which the speaker seeks information from the listener. The search for information is expressed as an inquiry. In an inquiry, the emphasis is on whether or not the question implies a genuine search for information about a certain topic, rather than on surface features such as the syntax of the statement (i.e., whether the question is formulated as an interrogation or not). To describe these types of questions, the authors developed a hierarchy of question types that encompassed different types of language categories in the form of speech acts (Graesser et al., 1992). Speech-act categories allow capturing both inquiries that are indeed interrogative expressions (e.g., What is a factorial design?) as well as non-interrogative inquiries that constitute a search for information (e.g., Tell me what a factorial design is). Therefore, these taxonomy questions were characterized as either an inquiry or an interrogative expression, or both. Moreover, the authors not only considered types of speech acts but also the degree of specification the person answering the question must rely on in order to understand the question. For instance, the question "What do polar bears eat?" has a higher degree of specification than "What do they eat?" Since these were natural conversation questions the degree of specification was determined by the knowledge shared by both participants.

Other criteria for classification of questions in this taxonomy consisted of whether categories were based on semantic, conceptual, or pragmatic features (i.e., speech acts), rather than on syntactic or lexical ones (e.g., question stems such as why, what, how, etc.). One reason for not considering syntactic or lexical criteria was that the same question stem (or form) may generate very different question types conceptually. For example, the question "How do sharks have babies?" is different from "How many babies does a shark have?" In the former case, the question is eliciting an explanation whereas in the latter case the question is requesting simple quantification. It is proposed that the distinction between a procedural or explanatory request versus a quantification request implies a significant conceptual contrast that would not be captured if the questions were categorized syntactically or lexically. Lastly, this taxonomy was developed with the goal of understanding the mechanisms that prompted the generation of questions during oral conversations (e.g., correction of incomplete or erroneous knowledge, monitoring shared information among speakers, and monitoring the flow of the conversation among speech participants). The development of the hierarchy served this primary goal by focusing on a range of inquiries rather than on interrogative expressions (Graesser et al., 1992). The following are some of the categories around which Graesser et al's question hierarchy has been organized:

Short Answer Question: Verification. Example: Is the answer five?

Short Answer Question: Disjunctive. Example: Is the variable gender or female?

Quantification: Example: How many degrees of freedom are in this variable?

Comparison: Example: What is the difference between a t-test and an F-test?

*Causal Antecedent: Example: How did experiment fail?

*Causal Consequence: Example: What happens when this level decreases?

*Instrumental/Procedural: Example: How do you present the stimulus on each trial?

*Enablement: Example: What device allows you to measure stress?

* Denotes deep-reasoning questions

(Extracted from "Inferring what the student knows in one-to-one tutoring: the role of student questions and answers." Person, Graesser, Magliano, & Kreuz, (1994)).

Another question hierarchy that deserves attention because its emphasis is on content rather than on question-form is the one developed by Cuccio-Schirripa et al. (2000). This hierarchy was developed to examine middle school students' questions in science. To develop this hierarchy, seventh-grade students were instructed in the formulation of higher-level researchable questions. These questions were defined as meaningful problems in science that had to be identified and constructed by the students themselves. A researchable question should also lead to deeper understanding. Different from other research in which the teaching of questioning had the purpose of improving reading comprehension, these authors wanted to focus on self-developed, researchable questions that led to deeper understanding of science knowledge. Researchable questions were characterized by unknown answers that needed to be searched by exploration, investigation, and experimentation. These questions were categorized on a 1 to 4 scale. Level 1 questions required yes/no or factual responses (e.g., How many meters deep is Lettuce Lake?) and Level 4 questions required cause-effect explanations with a high degree of specificity (e.g., To what degree does the volume of the air inside a ball influence the number of times a basketball will bounce?).

Both Graesser et al's (1992) and Cuccio Schirripa et al's (2000) hierarchies revealed a thorough analysis of question types, especially because of their content-based emphasis. In both question hierarchies, the emphasis is content-based because questions are categorized in terms of their content request rather than in terms of their linguistic form or syntax. In both hierarchies, high-level questions tap into explanations that go beyond what is explicit in the context in which the questions are generated, be it the type of information requested from conversation participants (Graesser et al., 1992) or researchable questions in science education (Cuccio-Schirripa & Steiner, 2000).

Even though the main goals for each of these taxonomies were qualitatively different, in both cases, a hierarchy of questions is presented. Beyond their specific contributions to their knowledge domains, in both hierarchies, question levels are characterized in relation to the answers that they request. Furthermore, in both hierarchies, higher quality or higher-level questions are characterized by the type of knowledge requested, as well as by the knowledge contained within the questions. For instance, in the hierarchy for science questions, researchable questions require from the questioner knowledge about specific variables and their interaction. Thus, it appears that when defining question levels, there is attention to the relationship between knowledge expressed within the question as well as knowledge contained in the potential answer to the question. Once again, the role of prior knowledge is emphasized in terms of the formulation of the question. Based on this, it can be speculated that advanced or higher-level questions in a given hierarchy are characterized by both the prior-knowledge contained *within* them as well as by the type of answer that they *request.* Higher-level questions seem to contain knowledge that is specific (e.g., a supporting fact in relation to a process or concept) while inquiring about an aspect of that knowledge.

Less elaborate or lower-level questions, on the other hand, may contain no specific knowledge in their formulation. For instance, in reference to the same science hierarchy, lower-level questions will probably focus on definitional or quantifying aspects (e.g., How many meters deep is that lake?). These lower-level questions may bear similarities to the "orientation to a topic" or "definitional" questions discussed by previous research (e.g., Scardamalia & Bereiter 1992; King & Rosenshine, 1993). The commonality for these lower-level questions is a request for facts or details, rather than a request for descriptions or explanations. As discussed, some investigators (Graesser, Langston, & Bagget, 1993) underscored these factors by emphasizing that prior knowledge manifests itself in the formulation of questions that do not focus on basic or definitional aspects of a particular knowledge domain, but rather, inquire about the interrelation of concepts within that domain.

Even though the argument about differences between lower and higher-level questions is speculative at this point, it is the characterization of questions within levels or categories that allows the advancement of these speculations. Therefore, a hierarchy of question types that distinguishes between higher and lower question levels that could be related to degrees of knowledge seems a necessary contribution to the area of student questioning.

Advantages of a question hierarchy. As previously discussed, it is clear that question types and outcome measures for reading comprehension have varied throughout the literature on student questioning. Additionally, no unified theory of questioning that relates levels or types of questions to degree of conceptual knowledge built from text exists. Utilizing a question hierarchy that defines questions in terms of their conceptual complexity would facilitate examining this type of relationship.

Furthermore, such a hierarchy would be favorable for instruction in question-generation. A hierarchy will help to describe individual differences in terms of question types or levels. Students could be described in terms of their position along a question-quality continuum, and goals for growth could be set in relation to these positions. A question hierarchy also supports the development of instructional practices that refer to higher and lower levels of questions, helping teachers set instructional benchmarks or goals defined by types of questions that encompass meaningful learning, while assisting students to become better inquirers.

A question hierarchy, as opposed to a typology or a taxonomy, is an ordered scale in which higher-level questions tend to subsume lower level ones. Within a hierarchy, a question at a given level is a request for information that is more inclusive than requests at lower levels. In the hierarchy described in this dissertation, questions vary in the degree of conceptual or content complexity they request. Therefore, for a given knowledge domain, higher levels in this question hierarchy will imply questions that are more inclusive and subsuming than lower-level questions in terms of the complexity of the information they request. Higher-level questions inquire about concepts or processes rather than about isolated facts, as lower-level questions do. Higher-level questions also elicit information about relationships among concepts, calling for knowledge that is interrelated and conceptually structured. Higher-level questions, subsume lower-level questions because requests for conceptual knowledge subsume knowledge of more specific and less inclusive propositions, such as facts or specific attributes. Facts and attributes serve to explicate and constitute evidence behind the concepts which are the focus of inquiry of high-level questions.

Therefore, in the Questioning Hierarchy presented in this study, lower-level questions are more specific and less inclusive because they tend to inquire about facts and attributes that do not necessarily connect with other facts or concepts. This circumscribes the potential answers to these lower-level questions to a limited and concrete aspect of knowledge. On the other hand, higher-level questions are inclusive because their requests tend to subsume factual information called for in lower level questions. In addition, higher-level questions request information about essential relationships among facts that relate to processes or concepts within the knowledge domain. These questions may request explanations about a single concept or they may tap into relationships among concepts, denoting knowledge that is integrated and conceptually structured. As it will be discussed in detail in the conceptual knowledge section of this literature review, knowledge that is conceptually structured is characterized by depth and breadth (Alao & Guthrie, 1999) and by its inclusiveness (Chi et al., 1994). Thus, questions that call for this degree of knowledge focus on conceptual relations and call for conclusive evidence. In other words, by focusing on conceptual relationships within a knowledge domain, higher-level questions inquire about the differentiation and inclusiveness of conceptual knowledge within that domain.

Hierarchy for questions in ecological science texts. The Questioning Hierarchy developed for the domain of ecological science is organized into four levels of questions. Each question level has two subcategories within it: (a) Text About Animals and (b) Text About Biomes. The first subcategory refers to text-referenced questions for a text consisting of an animal-related passage. This text is briefly described in the section Attributes of Expository Text in this chapter and is described in greater detail in the Materials subsection of the Method section (chapter IV). The second subcategory within each level, Text About Biomes, refers to a longer text version consisting of a reading packet that simulates multiple texts about biomes. This text is thoroughly described in the Method section (chapter IV). The content in this packet consists of two specific biomes and the animals that live in them. Nine ecological concepts are covered in these texts. A shortened version of the question hierarchy used in this study is presented next. The full version of this hierarchy is included in Appendix B.

Table 2
Questioning Hierarchy

Level	Question Characterization
Factual Information-Level 1	Request for a factual proposition. Question asks relatively trivial, non-defining characteristics of organisms or biomes, e.g., How much do bears weigh? Question is simple in form and requests a simple answer such as a fact or a yes/no type of answer, e.g., Are sharks mammals?
Simple Description-Level 2	Request for a global statement about an ecological concept or a set of distinctions to account for all forms of a species, e.g., How do sharks mate? Question may also inquire about defining attributes of biomes, e.g., How come it always rains in the rainforest? Question may be simple, but answer may contain multiple facts and generalizations.
Complex Explanation-Level 3	Request for elaborated explanations about a specific aspect of an ecological concept, e.g., Why do sharks sink when they stop swimming? Question may also use defining features of biomes to probe for the influence those attributes have on life in the biome, e.g., How do animals in the desert survive long periods without water? Question is complex and answer requires general principles with supporting evidence about ecological concepts.
Patterns of Relationships-Level 4	Request for elaborated explanations of interrelationships among ecological concepts, interactions across different biomes or interdependencies of organisms, e.g., Do snakes use their fangs to kill their enemies as well as poison their prey? Question displays science knowledge coherently expressed within the question. Answer may consist of a complex network of two or more concepts, e.g., Is the polar bear at the top of the food chain.

Impact of Questioning on Reading Comprehension

In this dissertation, I examined the association that question levels had with reading comprehension as characterized by conceptual knowledge built from expository science texts. Specifically, I hypothesized that levels of student self-generated questions in the content domain of ecology would be associated with degrees of conceptual knowledge built from text in ecological science. Students' self-generated questions were categorized according to the question- levels defined in the question hierarchy described earlier. Conceptual knowledge was categorized into degrees or levels of knowledge built from text. In order to describe the measures that assessed conceptual knowledge, a brief overview of the theoretical roots of conceptual knowledge seemed necessary.

Conceptual knowledge built from text can be represented in the form of mental models (e.g., Chi, de Leeuw, & La Vancher, 1994) or semantic networks. When conceptual knowledge is conceived as mental representations, knowledge is described as structures in which the main components and relationships in a knowledge domain are clearly identified (e.g., Chi et al., 1994; Alao & Guthrie, 1999). On the other hand, when conceptual knowledge is represented as semantic networks, knowledge is still conceived as a structure conformed by elements and relationships among them, but the emphasis is placed on *nodes* as incidences of meaningful ideas or concepts.. Pathfinder networks could be described as similar to knowledge representations conveyed by semantic networks although some differences exist. In either type of representation, a high degree of conceptual knowledge is characterized by identification of the main concepts in a knowledge domain and by the interrelationships among them and their supporting information.

In this dissertation, conceptual knowledge was measured by instruments that captured the essence of conceptual knowledge as both mental models and semantic networks. A knowledge hierarchy was used to assess students' conceptual knowledge characterized as mental models. Conceptual knowledge characterized as semantic networks was measured by a computer-based assessment that uses a program called Pathfinder. In order to understand further what is meant by conceptual knowledge, in the next section, I turn to the literature in this area.

Conceptual Knowledge

Conceptual Knowledge Built from Text

The ultimate goal of reading in most academic and school settings is that students *learn* from text. Learning from text has been defined as "…recognizing the depicted facts or events, to connect them to each other and to background knowledge and to memorize the results so they can be used later" (van den Broek & Kremer, 2000, p. 1). When reading is successful, this learning takes place and a coherent representation of text is built. A coherent representation is similar to a network, with nodes that depict the individual text elements (e.g., events, setting, facts) and connections that depict the meaningful relationships between the elements in the text (Trabasso, Secco, & van den Broek, 1984; van den Broek & Kremer, 2000).

Conceptual knowledge implies interconnections among nodes of knowledge and refers to a network of concepts and the relationships among these concepts (Chi, deLeeuw, Chiu, & Lavancher, 1994). Therefore, when it refers to text, conceptual knowledge entails a representation of the network of relationships among the elements in the text. Van den Broek and Kremer (2000) state that what makes a mental representation of text coherent are the relations between the elements that readers must infer (van den Broek & Kremer, 2000). Essential to building these relations are not only relationships among text elements, but associated concepts in background knowledge (e.g., Kintsch, 1998). The process of successful comprehension involves this integration between text information and background knowledge. A coherent text representation has thus been defined as a situation model (Kintsch, 1998), for which a higher level of integration has occurred as compared to a text-base representation. The higher level of integration is given by text explicit information that is meaningfully integrated with the prior knowledge of the reader (Kintsch, 1998). Meaningful integration assumes the establishment of relationships among text elements and formation of a coherent network (van den Broek & Kremer, 2000).

This view of reading comprehension purports a process that takes place between reader and text in which the reader is “simultaneously extracting and constructing meaning through interaction and involvement with written language” (Snow, 2002, p.11). This definition contrasts with other views of comprehension where the emphasis is on the social environment that the reader comes from and the impact that this has on text comprehension. One such view is espoused by Gee (2000):

> In reading, we recognize situated meanings (mid-level generalizations / patterns / inferences) that lie between the “literal” specifics of the text and general themes that organize the text as a whole. These situated meanings actually mediate between these two levels.” (p. 200)

Under this definition of reading comprehension, readers operate with different cultural models of what it means to read a text. Gee (2000) provides examples of readers who have cultural models of reading that stress social contacts and relationships between people. These readers operate with their models of reading and use them when attempting to make sense of a given text. A reader reads “from her own experience to the words and back again to her social experience” (Gee, p.201).

This “situated” view of reading comprehension contrasts with the view upheld in this dissertation for which the meaning of a text resides, to a higher extent, on the text itself. Even though the process of comprehension is hereby defined as an “interaction” between reader and text, the reader constructs meaning by bringing his prior knowledge to a text that is more objectively defined and shares a common base of characteristics for most readers.

Types of knowledge. Cognitive psychology has often distinguished among different types of knowledge. The traditional distinction has been declarative, procedural, and conditional knowledge. Declarative knowledge represents awareness of facts, events or ideas. This type of knowledge has been described as *knowing that*, mainly because the objects of this type of knowledge can be described. However, this does necessarily imply the ability to use this type of knowledge (Ryle, 1949).

Procedural knowledge has been defined as *knowing how*. This type of knowledge describes how learners use or apply their declarative knowledge (Ryle, 1949). Shaping plans, solving problems, and building arguments are all forms of procedural knowledge in which relevant declarative knowledge must be accessed and interrelated to be applied to the particular demands of the situation (Jonassen, Beissner, & Yacci, 1993). Procedural knowledge is the compilation of declarative knowledge into functional units that use domain-specific procedures (Alexander & Judy, 1988). Lastly, conditional knowledge refers to knowing *when* and *where* to access and apply certain procedures (Alexander & Judy, 1988).

A form of procedural knowledge is strategic knowledge. Strategic knowledge consists of goal-oriented procedures that are intentionally evoked, either prior, during or after the performance of a task (Alexander & Judy, 1988). Pre-reading strategies such as activation of prior knowledge, help readers to make inferences and elaborations while reading, whereas a strategy used during reading, such as identification of main ideas, helps readers better understand text, make judgments about the importance of information, and consolidate information succinctly (Paris, Wasik, & Turner, 1991). Strategies used after a task can either be the same strategies used prior or during the performance of the task, or a different strategy such as summarization which can help students with selecting and generalizing important ideas. Strategies used before, during, or after reading, foster reading comprehension by improving text processing (Paris et al., 1996).

Even though some researchers might categorize strategic knowledge as a type of procedural knowledge, a more in-depth examination of strategic knowledge evinces that this can also be described also as declarative knowledge –knowing *what* strategies are available and can be used. However, researchers argue that the mere awareness of strategies to manage one's reading does not guarantee that students will use those strategies effectively in a spontaneous way (Paris, Wasik, & Turner, 1991). Therefore, knowledge of how and when to use them, procedural and conditional knowledge, is necessary for students to regulate their own learning and reading through the use of strategies for different purposes. The extensive description of strategies into several categories (e.g., goal limited vs. general strategies; metacognitive strategies; prior, during, and after reading strategies) has fostered the distinction of all three types of knowledge within the realm of strategic knowledge. Declarative knowledge has been described in terms of knowledge or awareness of what strategies are available to the learner, procedural knowledge has been described in terms of knowing how to use a particular strategy, and conditional knowledge is knowing when and where to use that particular strategy.

Conceptual knowledge. In this investigation the focus is on a type of knowledge that deals with specific aspects of declarative and procedural knowledge. This type of knowledge has been referred to as structural knowledge by some researchers (Jonassen, Beissner, & Yacci 1993; Diekoff, Brooks, & Dansereau, 1983) and as conceptual knowledge by others (Tennyson & Cocchiarella, 1986, Alao & Guthrie, 1999). In this study, I will use the term conceptual knowledge, even though I refer to the same characterization that other researchers have made of structural knowledge, i.e., conceptual knowledge is knowledge that is structurally represented.

The focus of conceptual knowledge is *knowing that* (i.e., declarative knowledge) with an emphasis on the relationships of concepts within a domain. "Structural knowledge provides the conceptual basis for *why*; it describes how the declarative [knowledge] is interconnected" (Jonassen et al., 1993). Structural or conceptual knowledge refers to the relationships among concepts within a domain or a topic and to the understanding of those relationships. In this sense, conceptual knowledge is more elaborate than declarative knowledge because it is the "understanding of a concept's operational structure within itself and between associated concepts" (Tennyson & Cocchiarella, 1986), rather than knowledge of facts or concepts independent of their relationships with each other. Indeed, structural or conceptual knowledge integrates declarative knowledge into knowledge structures because it assumes that the meaning for a given concept or construct is implicit in the pattern of relationships to other concepts or constructs (Jonassen et al.,1993).

Conceptual knowledge refers to an individual's organization and integration of concepts or constructs in a knowledge structure. Information processing theorists have referred to knowledge structure as organized networks of information stored in semantic or long-term memory (Kintsch, 1974). Other researchers have emphasized the organizational and integrative essence of conceptual knowledge. Within a network of information, these researchers suggest that concepts and ideas that have more connections to other concepts take on a more central role in knowledge representations and are most easily remembered (Goldman & Rakestraw, 2000).

Concepts. A thorough understanding of conceptual knowledge requires defining the intrinsic elements of this construct: concepts. When Piaget referred to concepts, he did so in the framework of his epistemology by describing schemata, as well as concepts. Schemata refer to enduring, “goal-directed” action sequences used across different situations, whereas “Concepts differ from schemata in that (they) are not goal-directed procedures as much as forms of understanding that involve relations among things or aspects of things” (Byrnes, 1992b). Piaget focused on concepts such as time, conservation, causality, space, number, and class inclusion and studied how these evolved in children’s knowledge development. Different from schemata, concepts for Piaget involved categories that explained relations among objects or aspects of entities. The concept of time, for example, involves the relationship between causes and effects (Piaget, 1969). Byrnes (2001) also underscored another distinction between schemata and concepts within Piagetian theory: Children at all ages seem to possess schemata, whether physical or mental, but only older children, adolescents, and adults possess concepts (Byrnes, 2001). This is so because concepts are characterized by abstraction and generalization, two features that require time and experience to develop. Thus, for example, the concept of time implies the ability to abstract and generalize across multiple contexts in such a way that the same interval of time will be true for all objects and situations to which this refers (Byrnes, 2001).

The abstract, generalizable, and in particular, the relational nature of concepts has also been underscored by describing concepts as involved in a vast network of relations of meaning: “A concept can be thought of as a theoretical point where meaningful relations converge, and each concept is a crossing point for a multitude of relations…we find a concept as part of a semantic network, its meaning arising from a multitude of crisscrossing prepositional relationships” (Pines, 1985, pp. 109-110). Furthermore, concepts have also been described as evolving units of meaning that shift as learning takes place. In this sense, concepts are seen as elements with flexible meanings that are reconstructed within a knowledge network. However, despite the flexible meaning of concepts, the knowledge network that defines how concepts are constructed is conceived as relatively permanent (Kintsch, 1998). “Concepts do not have a permanent and fixed meaning. Rather, each time a concept is used, its meaning is constructed in working memory by activating a certain subset of the propositions in the neighborhood of a concept node” (Kintsch, 1998, p. 75). In other words, it is the context that determines which aspects linked to a concept are activated when this is used.

Theoretical basis for conceptual knowledge. Theoretical roots for structural or conceptual knowledge come from two main sources: semantic networks or active structural networks (Quillian, 1968; Norman, Gentner, & Stevens, 1976), which in turn are based on schema theory (Rumelhart, 1980; Rumelhart,1978). Semantic networks have been described as cognitive structures composed of nodes (or schemas) with relationships connecting them (Quillian, 1968; Norman et al., 1976). In semantic networks, nodes are incidences of meaningful ideas or concepts and the links represent the interrelationships among them.

A schema has been defined as a “prototype of meaning” or as a “procedure” whose function is to determine whether its constituent structure can account for a pattern of observations (Rumelhart, 1980). A schema, then, appears to be more encompassing than a concept since a schema is a representation of knowledge about different concepts such as events, sequences of actions, situations, objects, etc. Furthermore, schemas are units of knowledge that contain specification about how knowledge is to be used in different occasions (i.e., instantiation of a schema). As such, a schema has been defined as a data structure for representing the generic concepts stored in memory (Rumelhart, 1980).

Even though schemas vary in specificity (e.g., event schemas versus object schemas), it is the interrelationships between schemas that contribute to their representation in memory. Furthermore, these knowledge representations are semantically organized in memory, mainly because schemata are arranged in networks of interrelated meanings. Knowledge about word meanings or concepts is represented not in abstract forms or single generalizations, but rather as a contextual interaction of concepts (Anderson & Nagy, 1991).

In summary, conceptual knowledge is a cognitive construct with its theoretical basis on semantic network and schema theories. According to its theoretical roots, conceptual knowledge is characterized by a distinct set of concepts with a well-defined understanding of the hierarchical relations that structure the network of those concepts.

Semantic networks and mental models and as representations of conceptual knowledge. The theoretical roots of conceptual knowledge then, characterize conceptual knowledge as structures composed of nodes with relationships connecting them (Quillian, 1968; Norman et al., 1976). According to the networking models of memory, memory is semantically organized in nodes that represent concepts, linked to other nodes in memory in some meaningful manner (Diekhoff, Brooks, & Dansereau, 1982). Therefore, a node can be characterized as the smallest functional unit of meaning or information represented within a knowledge structure that constitutes a network of relationships among concepts.

Semantic networks then, are representations of conceptual knowledge to the extent that conceptual learning is seen as a reorganization of the nodes or concepts within the net. Semantic nets are generally characterized by a hierarchy of ever more specific nodes (e.g., animals in general to mammals to specific kinds of mammals). Knowledge that is more general or encompassing is held at nodes representing it and is not repeated at nodes that are more specific, but to which knowledge applies (Groome, 1999). Based on computational models of knowledge and their use for lexical decision tasks, of semantic networks focus on processes of activation of nodes and on how this activation spreads across different concept nodes so word meanings become readily available for further processing (Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1983).

Pathfinder networks are used as one of the measures to represent and assess conceptual knowledge in this dissertation. Pathfinder networks differ in two main ways from semantic network representations. First, in semantic networks the inter-node links are explicitly labeled, whereas the links in Pathfinder networks are unlabeled. Even though the links in Pathfinder could be categorized (see section: *A Pathfinder example on The Killer Whale*), this is not a feature of this technique. When faced with the question of whether there could be any semantics in a network with unlabeled links, Pathfinder theorists assume that "to the extent that a derived representation has predictive validity it also contains a degree of semantic relevance" (Goldsmith & Johnson, 1990, p.244). Second, Pathfinder networks are capable of representing knowledge in the form of a single score for a network. This renders a more global, less node-by-node, representation of knowledge than semantic networks do. This is so because Pathfinder networks can be associated with patterns of links that are meaningful to experts (Goldsmith & Johnson, 1990).

Mental models, however, can represent conceptual knowledge as well. A central feature of mental models is that these are a representation of knowledge of a specific nature or knowledge in a given domain, rather than being a general knowledge structure such as script (Schank & Abelson, 1977). Chi, de Leeuw, Chiu, and LaVancher (1994) defined mental models as mental representations of knowledge occurring with deep understanding. In their study, mental models were based on the number and quality of the statements made by a student. A high integration of these statements characterized rich and sophisticated mental models. Students who built high and complex mental models included elaborate statements describing the functioning, behavior, and structure of the components of the human circulatory system, as well as relationships between the components (Chi et al., 1994). This characterization highly agrees with the procedures used for measuring and coding conceptual knowledge in this dissertation (see section *Characteristics of the knowledge hierarchy* in chapter III).

Conceptual Knowledge Representations for Narrative and Expository Texts

Different genres or types of discourse imply different structural compositions (Graesser, Golding, & Long, 1991). Concepts or nodes, then, will vary in their characterization according to the features of the particular knowledge structure they constitute. Narratives, for instance, refer to event sequences that might entail real or fictitious characters. The characters have intentional actions in order to achieve certain goals and the events take place in the material world (Graesser, Golding, & Long, 1991). Stories, in particular, conform to an episodic structure organized around the goals, needs, and obstacles encountered by a main character (Trabasso, Secco, & van den Broek, 1984). Furthermore, narratives are generally based on event sequences and experiences that are familiar to individuals in a culture. Thus, meaning can be constructed by drawing from a rich source of everyday knowledge (Graesser, Golding, & Long, 1991).

Expository texts, in contrast, are written to convey information with clarity and precision by presenting new information that explains principles and general patterns. Concepts, ideas, and relationships in these texts tend to be very explicit, trying to avoid forcing the reader to fill in conceptual gaps (Graesser, Golding, & Long, 1991). In addition, expository or information texts are not characterized by the predictable sequence that stories share (main character-problem-resolution), but are organized in multiple ways, thus making organization and prediction of ideas more difficult for novel readers (Ogle & Blachowicz, 2002).

Therefore, because different text genres vary in terms of their structure, their content, and purpose (Alexander & Jetton, 2000), conceptual knowledge representations for different genres may very well vary in terms of the specific characterization of nodes and the relationships among them. In order to discuss some of the differences in knowledge representations, I turn next to a couple of representations of conceptual knowledge for expository and narrative texts.

Conceptual knowledge representations for expository texts. A knowledge domain in which researchers have discussed conceptual representations of expository texts has been geology (Champagne, Klopfer, Desena, & Squires, 1981). Researchers in this domain used a conceptual knowledge representation of geology as communicated through scientific writings of experts in the discipline. By using representations of geological concepts derived from experts' writings, conceptual knowledge representations of geology maintained the scientific integrity of the discipline. These experts' representations were used as standard knowledge structures against which the students' knowledge representations could be judged (Champagne et al., 1981). These researchers have selected the particular topic of minerals and rocks, which was primarily descriptive, physical geology. Eighth grade students were presented with illustrated texts in which hierarchical relationships among major concepts and examples of concepts within this topic were given. Another topic emphasized in the texts was cyclical relations of rock transformations.

Conceptual knowledge was assessed in terms of students' ability to relate pairs of concepts and arrange concepts into larger, hierarchical structures. Concepts were represented by terms (words or phrases) selected from text and presented for the students to relate and organize in three topically based sets. For example, the first set titled *Atom* included five concept terms: chemical compounds, chemical substances, chemical elements, and molecules. For the other two sets, *Minerals* and *Rocks*, some of the concept terms included calcite, calcium carbonate, graphite, shells of sea animals, carbon, and limestone. for the minerals topic, and granite, igneous, lava, sedimentary, magma, and marble were concept terms for the rocks topic. Students had to arrange the terms within a given set based on how they thought the terms related to each other. Relationships between terms were labeled with the relationship the student provided. Students' conceptual knowledge representations were assessed in terms of how closely they matched the standard represented by the experts in the discipline.

It should be noted that the emphasis in this investigation was on students' ability to *relate* the terms and explain those relationships. However, this relational emphasis for each topic was very much dependent on the word set provided and on how the words were organized in the text. For example, for the particular conceptual structure of physical geology, classification of rocks and minerals was central. Thus, experts' conceptual representations would most often depict a hierarchical class inclusion structure for this topic. Alternatively, an expert could produce a conceptual representation that highlighted the cyclical rock transformation relations (e.g., limestone changes into marble) changing or adding significantly to the hierarchical class-inclusion structure. Thus, as previously stated, representations for conceptual knowledge are tightly linked to the structural organization of the genre and the domain that they characterize.

One of the features that these investigators considered important for knowledge to be characterized as conceptual was parsimony (Champagne et al., 1981, p. 103). That is, a knowledge structure should avoid redundant information in reference to the relationships it depicts. Information is rendered redundant when it adds no meaning to the overall structure because this is already implied in the hierarchy of the structure.

Taking into account the parsimony requisite and the conceptual knowledge representations for the topics of minerals and rocks by experts in the discipline, these researchers described complexity within the knowledge structure in terms of six dimensions. These dimensions consisted of: (1) two or more words represented with unspecified relationships; (2) two or more words related by a single technical or general usage level; (3) fragments of the hierarchical (i.e., classification) and/or transformational structures (i.e., cyclical rock relations); (4) hierarchical structure or transformational structure; (5) hierarchical structure plus fragment of transformational structure; and (6) integration of hierarchical structure and transformational structure into a single structure.

It is evident that an increase in complexity from dimension 1 to dimension 6 implies a higher number of words/items or concepts represented. However, higher complexity also suggests strength in the relationships between concepts (e.g., an unspecified relationship versus a scientific relationship). Finally, moving from a lower dimension to a higher dimension also implies signaling whether the conceptual structure refers to the hierarchical class inclusion of rocks and minerals versus the transformational relations of rocks, or if it includes both types of knowledge structures (i.e., Level 6).

Therefore, higher complexity within this type of knowledge structure entails at least three levels of analyses. On the one hand, higher levels of knowledge imply distinction of relationships among the concepts that are specifically defined for the topic. On the other hand, higher knowledge complexity requires integration of knowledge at two structural levels: (1) classification (class inclusion) and; (2) rock cycle transformations. Thus, for instance, if a knowledge structure includes terms such as limestone, granite, and marble and labeled relationships indicate that these are all types of rocks, the structure incorporates the class inclusion hierarchy. If, in addition to the class inclusion hierarchy, the knowledge structure includes concepts such as igneous and metamorphic (rock properties) and has labeled these as types of rocks and as part of the rock cycle transformation, then both levels of analyses are being included. This increases knowledge complexity. Thus, for this particular knowledge domain and topic, higher knowledge complexity is defined by structures that represent the main concepts in the topic as well as the relationships among these concepts in reference to their multiple features (i.e., rocks as types and rocks as part of cyclical transformations).

Mental models as representations of conceptual knowledge in life science domains. Researchers have also characterized conceptual knowledge as the integration and differentiation of science concepts (Pine & West, 1986; Chi, de Leeuw, Chiu, & LaVancher, 1994). Knowledge of science concepts that is integrated, inferred and differentiated has been examined in reference to specific life science topics, in particular the human circulatory system (Chi, de Leeuw, Chiu, & LaVancher, 1994). These researchers have contributed significantly to the understanding of the quality and the organizational structure that conceptual knowledge built from text can have. Two broad categories of knowledge were identified, local and systemic knowledge. Local knowledge refers to the features and functions of the individual components of the circulatory system. Systemic knowledge pertains to the knowledge of the interaction of the components of the system with each other. According to the authors, systemic knowledge is often scarce in textbooks on the topic. One advantage of emphasizing systemic or integrate knowledge is that the understanding of relationships among components of a system facilitates the generation of inferred knowledge. For example, for an individual component in the circulatory system, such as the atrium, local knowledge would refer to knowledge of one of its features, such as its function as a blood-holding reservoir. However, if this local knowledge is related to the function of another component of the circulatory system, such as the behavior of the valves of the heart, knowledge becomes systemic. By its integrated nature, systemic knowledge, like conceptual knowledge, implies knowledge about relationships between elements in a structure that in turn facilitates inferential knowledge. In this particular domain, systemic knowledge facilitates inferences such as the understanding of health consequences like having a leaky valve (Chi et al., 1994). Chi et al. (1994) found that college students who constructed knowledge structures with these characteristics had mental models that corresponded to high conceptual knowledge that included several accurate features and functions. Therefore, for this knowledge domain high conceptual knowledge involves relationships among local features (e.g., how the structure of the atrium relates to its function) as well as relationships of local features to system-wide features (e.g., how the structure and function of the atrium relates to plumping blood to the lungs and returning blood to the heart).

Evidence of mental models corresponding to high conceptual knowledge in this study is similar to the view of high degrees of conceptual knowledge defined by Champagne et al. (1981) for geology expository texts for eighth-grade students. In both studies, students' conceptual knowledge consists of an understanding of the elements that are part of a system (e.g., the human circulatory system or the cyclical transformation of rocks), as well as a grasp of how these elements relate to each other to explain classifications, processes, or a series of events. Classifications, processes, or classes of events or behaviors can be described as concepts within these domains. They are concepts because they transcend the particulars of an event, fact, or object to explain processes that pertain to a group of elements, events, or objects within a structure or system. If, in addition, the learner possesses knowledge about relationships among concepts knowledge is "systemic", integrated, or conceptual. Knowledge of relationships among concepts, organized into a hierarchy, denotes a macro-level of understanding, in which concepts can be identified as superordinate and subordinate based on their features and relationships with other concepts in the domain (Chi et al., 1994).

Consistent with this notion, conceptual knowledge has also been described by its breadth and depth (Chi et al., 1994; Alao & Guthrie, 1999). Breadth represents the major sectors of a specific domain (Alao & Guthrie, 1999). For instance, a student who knows the meanings and definitions of predation, reproduction, defense, food chain, locomotion, communication and adaptation to habitat has knowledge breadth, since her knowledge represents the major ecological or biological concepts that pertain to a given organism. However, if the same student knows not only the ecological concepts but also the relationships among those concepts, her knowledge is characterized by breadth *and* depth.

Conceptual knowledge representations for narrative texts. Within the narrative genre, there have been models of knowledge representation of text like story grammars (Mandler, 1984; Rumelhart, 1978) and causal network theories (van den Broek, 1988; van den Broek & Trabasso, 1986). I chose to describe these particular models of knowledge representations because they are thorough in the description of the elements in knowledge representations for narrative text.

Story grammars represent knowledge by a series of formal components (such as grammar rules and node categories) and conceptual relations based on the explicit phrases, clauses, and statements in a text. Common formal components to story grammars capture structural regularities in a class or group of stories. For example, setting, beginning, character's reaction, goals, and outcomes are types of information within the text. Each of these types of information can be assigned to node categories when the text is interpreted and represented as a story grammar. Even though different story grammars vary in the types of node categories and rules they have, most of them have in common semantic and conceptual constraints that limit the text information that can be assigned to different node categories. For example, a node corresponding to a character's simple reaction can involve an emotional or cognitive response (e.g., the princess was frightened), but not an intentional action (e.g., the princess ran away), making these two types of nodes mutually exclusive in terms of the text information they contain (Graesser, Golding, & Long, 1991). When applied to a specific story, this system of node categories, rules, and semantic and conceptual constraints constituting a story grammar assigns a hierarchical structure to the explicit information in the text. A limitation of a story grammar representation is that its structure can take care of explicit information within a story but cannot explain knowledge that is not explicit in the text such as inferential or prior knowledge (Graesser et al., 1991).

Other knowledge representations for narrative text have dealt with the limitation of story grammars for representing implicit knowledge. These systems have done so by incorporating components that include knowledge based-inferences generated during narrative comprehension. Such is the case of a theory of narrative comprehension that represents knowledge in the form of a conceptual graph structure (Graesser, 1981; Graesser & Clark, 1985). This model offers an explanation of the interaction between world or prior knowledge and the construction of text representation. In conceptual graph structures, statement nodes are proposition-like units that correspond to both explicit text statements as well as knowledge-based inferences. For instance, statement nodes can categorize either a state, event, goal, or style specification (e.g., an event occurred slowly). As other conceptual knowledge representations, links or arcs among nodes indicate that the nodes are related. Different from other networks of conceptual knowledge, relationships between the nodes are specified according to nine categories of links or arcs. For example, an event node such as “the daughters forgot the time” (event 1) is linked to another event node such as “the daughters stayed too long” (event 2) by a Consequence arc. In order for this arc or link to be placed between these two events, event 1 must temporally precede event 2 and must have a causal relationship with event 2, thus the label Consequence for this link. Other link categories are Reason (R), Outcome (O), Manner (M), and Implies (Im). Conceptual graph structures also have a series of constraints and rules (such as causal antecedent or temporal priority) for nodes to be related to each other that are imposed on the overall structure. As mentioned, world or prior knowledge is also represented in a conceptual graph structure. The theoretical perspective that conceptual graph structures assume is that prior knowledge is represented in the cognitive system as a set of generic knowledge structures (GKSs) and specific structures. Thus, when a specific passage is comprehended several GKSs are triggered through pattern recognition processes. Each GKS is a rich knowledge structure that contains more than a hundred nodes, which are generally more abstract (i.e. they contain more inferential information in them) than those in a specific structure (Graesser & Clark, 1985).

Similar to story grammars and other narrative models, the conceptual graph structure model postulates rules that predict which text statements are central, intermediate, or non central to the narrative. In other models, like story grammars or causal networks (Trabasso et al., 1984; Trabasso, & van den Broek, 1985), the set of rules that determines the hierarchical structure of text content has been expressed in terms of super-ordinate goals and subordinate goals. Super-ordinate goals or super-ordinate nodes are higher and more encompassing than subordinate goals or nodes because the former ones have many causal connections and are more inclusive than dead-end nodes.

Through the use of specific rules that define node categories and their relationships, Graesser's conceptual graph structure permits the configuration of how knowledge derived from narrative text is represented by the reader in a conceptual fashion. Other researchers (e.g., Williams, 2002) have been less explicit about the different elements and rules of the overall system for representing narrative knowledge, but have, like Graesser et al., emphasized that conceptual knowledge for narrative texts goes beyond the specific plot. One such case conceives understanding of the theme of a story as conceptual knowledge (Williams, 2002). "A theme expresses a relationship among story components in a form that is abstracted from the specific story context, and it comments on that relationship in some way. The commentary can take the form of a lesson (with a value judgment), as in a fable, or it can consist simply of an observation, with no value judgment attached ('Some people steal' or 'When he is hungry, a man may do bad things')" (Williams, 2002, p.128). What characterizes the theme as conceptual knowledge is that the commentary operates at the concept level rather than at the explicit plot level. This is so because the observation or morale can be generalized beyond the specificity of the story plot (Williams, 2002).

Distinctions between conceptual knowledge representations for narrative and expository texts. The representations of conceptual knowledge for narrative and expository texts described previously have in common the characterization of concepts (nodes) as included in networks of hierarchical relationships. Furthermore, breadth and depth of conceptual knowledge within a domain implies a firm understanding of the hierarchical relationships that define and explain the central concepts in that domain (Alao & Guthrie, 1999).

However, beyond the shared features that characterize conceptual knowledge across text-genres and knowledge domains, the specific node characterization and the nature of the relationships among these are constrained by the genre or knowledge domain. For example, for the narrative knowledge models described here, node categories referred to statements of narrative information assigned to the nodes, such as events, states, or goals (Graesser, Golding, & Long, 1991). On the other hand, for the geology expository texts, nodes were represented by terms or phrases relevant to the domain as judged by experts in the field (Champagne et al., 1981). Nodes, then, are units of meaning defined within the knowledge domain or text genre that they integrate. The same genre-specificity that applies to nodes pertains to the organization of knowledge in each genre. For instance, for narrative representations, semantic rules and conceptual constraints assign the hierarchical structure to representations such as story grammars and conceptual graph structures (Graesser & Clark, 1985; Graesser, Golding, & Long, 1991).

In contrast, for information texts the hierarchy of knowledge structures seems to be determined by knowledge standards set by experts in that discipline (Champagne et al., 1981; Chi et al., 1994).

Therefore, it appears that intrinsic to the characterization of conceptual knowledge is the organization of concepts and their interrelationships in a hierarchical structure. However, definitions or characterization of concepts, as well as the *types* of relationships among concepts that define the overall structure are genre or domain specific.

Attributes of Expository Text

So far, I have discussed the characteristics of conceptual knowledge both as representations of knowledge for expository and narrative texts. Part of the focus of this study is conceptual knowledge representations for expository texts. However, although knowledge representations have been discussed extensively, characteristics of expository text itself have not been presented.

Texts to be used in this study consisted of expository texts in the field of ecology. These texts are thoroughly described in the Materials subsection within the Method section of this dissertation. To provide a more accurate description of the type of text structure of these texts, I follow the characterization by Chambliss and Calfee (1998). These authors state that one of the differences between narrative and expository text is in the text structure of each type of writing. Narrative uses the plot as the primary linkage that drives the various characters as they move from the beginning of the story to the resolution. Expository texts, on the other hand, tend to describe a topic or explain a process and the links between text sections depend on whether the exposition is descriptive or sequential (Chambliss & Calfee, 1998). Description presents characteristics fixed in time like a snapshot (e.g. the population and landforms of the continents). A sequential information text presents events progressing over time (e.g., stages in a life cycle).

Within each of these subcategories, Chambliss and Calfee (1998) describe text designs that depict the elements and structure of each type of information or expository text. Descriptive texts can take the form of a list, a topical net, a hierarchy, or a matrix. Sequential texts, on the other hand, can take the form of a linear string, falling dominoes, and a branching tree. These seven designs are characterized as the building blocks for exposition.

Among the designs for descriptive-informational texts, the hierarchy and the matrix have the tightest and greatest number of linkages across text elements and ideas. Thus, these text designs can organize large amounts of content. Furthermore, representations of conceptual knowledge for expository texts have benefited from texts with hierarchical relations among the main concepts in the text facilitating students' conceptual representations (Champagne et al., 1981).

In this study, two expository texts in the domain of ecological science will be used. One type of text will consist of a packet that simulates multiple texts on the topics of biomes and animals. This multiple text packet consists of approximately 80 pages and is organized into 22 sections. Approximately eight sections describe general and specific attributes of each of two biomes in the packet. Eight sections describe features and ecological concepts that pertain to animals that inhabit the biomes. The six remaining sections function as "distractors" and are non-relevant to the overall topic of the packet.

Throughout each packet, topics vary in level of text difficulty. Text difficulty is differentiated by sentence length and paragraph complexity, with two types of text difficulty: easy and difficult. Further details on these multiple text packets will be provided in the Method section of this dissertation under the Materials subsection.

According to Chambliss and Calfee's (1998) taxonomy of texts, texts in this packet fit the category of a description. Each section in the packet is treated as a chapter that presents characteristics of biomes with no time reference as a sequence. In addition, because most sections deal with similar attributes (i.e., characteristics of a biome or features of ecological concepts of the animals in the biomes) the overall text design conforms to that of a "matrix", as characterized by Chambliss and Calfee (1998). A matrix is characterized by similarly organized text sections for which links across sections are easy to establish. This design is evident in the multiple text packet because each section deals with similar categories: characteristics of a biome, physical features of animals, and ecological concepts for these animals (e.g., adjustment to habitat, reproduction, defense, etc.).

The second text to be used in this study will consist of an animal-based passage. This is a four to five page text organized into approximately five sections. Each section has three to five short paragraphs. This passage describes survival aspects of a specific animal (e.g., sharks, polar bears, bats). An animal's survival is described by explicating essential features of four ecological concepts that serve as survival mechanisms for that animal. In this way, the passage is organized by having a short introductory paragraph on what survival represents for that specific animal and an elaboration on four ecological concepts (e.g., bats' feeding, hunting and killing, movement and defense). The design of this text conforms to a hierarchical description according to Chambliss and Calfee (1998). The hierarchical relationships in the text design are given by the short introductory paragraph that forecasts the significance of different survival mechanisms: the ecological concepts described in each section. When one refers to a conceptual knowledge representation, a hierarchy is given by each of the ecological concepts being subsumed under the overarching concept of survival. When one refers to text organization, each of these concepts is described in the sections following the introductory section on “survival.” This explains that the text design of this passage corresponds to a hierarchical description.

As it pertains to text content, Chambliss and Calfee (1998) consider that a good expository design should have themes that reflect expert models of principles in a given discipline. This is achieved by having text elements that are central to the discipline and by having linkages across elements that depict relationships important to experts in that domain. This is in line with the notion of using models of conceptual knowledge representations derived from experts’ writings in a domain (e.g., Champagne et al., 1981). This same notion is used in this study for which a model representation of conceptual knowledge for ecological science texts is given by experts’ knowledge representations in that domain.

Tools for Representing Conceptual Knowledge

As discussed, a network of relationships among concepts is what distinguishes conceptual knowledge from other types of knowledge. In this sense, conceptual knowledge is a hypothetical construct that can be reified through different techniques and graphic representations (Jonassen et al., 1993). There are different tools or techniques that can be used to represent conceptual knowledge. Some of these techniques such as concept maps, semantic maps, graphic organizers, and spider maps have been widely used as instructional tools (e.g., Ausubel, Novak, & Hanesian, 1978; Novak,1990). Other techniques, such as Pathfinder nets have also been used to represent conceptual knowledge (e.g., Acton, Johnson, & Goldsmith, 1994; Gonzalvo, Canas, & Bajo, 1994). Because Pathfinder was one of the tools used to measure conceptual knowledge in this study I describe it in detail toward the end of this subsection. Next, I briefly describe concept maps and graphic organizers as two of the instructional techniques used for representing conceptual knowledge.

Concept maps. Concept maps have been defined as tools used to represent knowledge structures in various disciplines and as aides in the organization and understanding of new subject matter (Novak, 1990; Novak & Musonda,1991). Concept maps are diagrams that illustrate relationships among concepts in a given content area, discipline, or topic (Jonassen et al., 1993). In consideration that some concepts are more inclusive and more salient than others, some authors have actually recommended that concept maps be drawn in a hierarchical form (e.g., Novak & Musonda, 1991). Concept words might be depicted as individual words, propositions, or phrases. Links that depict the relationships between concepts are labeled so that the relationship is explicitly identified. Most of the work on concept maps is based on Ausubel's assimilation theory, in which learning is meaningful only when it takes place in the context of the learner's prior knowledge (Ausubel, Novak, & Hanesian, 1978). Ausubel also proposed that knowledge structures are organized hierarchically with more inclusive concepts subsuming more detailed ones (Ausubel, Novak, & Hanesian, 1978). Therefore, concept maps, when conceived as representations of conceptual knowledge, are often hierarchically organized. Generally, more inclusive or more abstract concepts are positioned at the top of the maps and less inclusive or more concrete concepts are situated in lower positions on the map (e.g., Novak & Musonda,1991).

Graphic organizers. Graphic organizers are another class of spatial representation tools for conceptual knowledge. Like concept maps, graphic organizers are diagrams that communicate the organization of a text passage or a particular content domain by depicting concepts and their relationships through links. Unlike concept maps, links in graphic organizers are often unlabeled, and they represent unspecified relationships. Concepts are represented by nodes, which are generally single words depicted in boxes or circles (Jonassen et al., 1993). Both concept maps and graphic organizers are means of representing conceptual knowledge, as well as instructional tools used to convey and assess knowledge in classroom settings.

Pathfinder networks. Pathfinder networks are a graph-theoretic technique consisting of an algorithm that derives a representation of an individual's knowledge within a domain by using proximity data (Schvaneveldt & Durso, 1981). Proximity data consist of ratings of relatedness on all pair-wise combinations of concepts within a topic or knowledge domain (Johnson, Goldsmith & Teague, 1994; Schvaneveldt, 1990).
As discussed, the cognitive assumption for conceptual knowledge is that to be knowledgeable in a domain the interrelations among concepts in that domain must be understood. The assumption behind Pathfinder networks is that one tenable way to assess the cognitive changes that may occur with the acquisition of expertise in a knowledge domain is through judgments of relatedness among the central concepts in the domain

(Goldsmith & Johnson, 1990). In other words, an important feature of conceptual representations is that the pattern of relationships among concepts should be useful to differentiate among individuals with varying levels of knowledge (Goldsmith & Johnson, 1990).

The journey from novice to expert may be viewed as a continuous sequence of analysis and synthesis, with each successive cycle providing a more differentiated and integrated cognitive system… Judgments about what is like and what is different would appear capable of reflecting fundamental properties of the developing cognitive system. (Goldsmith & Johnson, 1990, p.245)

Proximity ratings or the relatedness between pairs of concepts then, are assumed to capture the underlying organization of knowledge. Similarity or proximity judgments render a matrix of ratings for the concepts. The scaling algorithm transforms the matrix of ratings into a connected graph that depicts the network of relationships among concepts (Johnson, Goldsmith, & Teague, 1994).

Pathfinder as a measure of conceptual knowledge. Validity for Pathfinder as a technique for capturing structural or conceptual knowledge has been mainly found for adult learners (Acton, Johnson & Goldsmith, 1994; Goldsmith & Davenport, 1990; Goldsmith, Johnson, & Acton, 1991; Gonzalvo, Canas & Bajo, 1994; Johnson, Goldsmith & Teague, 1994). For example, Pathfinder representations were compared to multidimensional scaling (MDS) spatial representations of the ratings and to raw proximity data. These techniques were compared in terms of their predictive validity of classroom performance in a psychology research course for junior college students (Goldsmith, Johnson, & Acton, 1991). Students' performance in the course was measured by three exams and two papers. Students rated the relatedness of 435 pairs of concepts (30 concepts) using a seven-point scale (1= less related; 7= more related). Four different knowledge indices were used in the analyses: correlations on raw proximities, correlations on MDS distances, correlations on Pathfinder graph-theoretic distances, and Pathfinder networks assessed by *C*. *C* is quantitative index (its values range from zero to one) of similarity between an expert's and a novice's networks which compares neighborhood regions of two networks (i.e., links for individual concepts across two networks). Pearson correlations were computed between each knowledge index and the students' earned points on the classroom tests and papers. All of these correlations were significant ($p < .01$). It was also found that distances from MDS were slightly poorer than raw data proximities (i.e., concept ratings) in predicting student performance, whereas Pathfinder distances were better than the raw proximity data. In order to examine more closely the contribution of each knowledge index, partial correlations were examined. It was found that Pathfinder networks, using *C*, correlated significantly with students' course performance even when the other knowledge indices were held constant. However, none of the other indices were found to correlate with final course grades if the variance contributed by the *C* index of Pathfinder was held constant. In addition, MDS did not significantly predict course performance when the other knowledge indices were partialed-out. Therefore, it was concluded that Pathfinder offered a valid assessment of students' knowledge representations and students' course performance.

Other studies have examined the role that Pathfinder has in distinguishing different levels of expertise. For example, Cooke and Schvaneveldt (1988) distinguished between expert, intermediate, and novice computer programmers' knowledge structures based on their Pathfinder networks. Expert programmers were better able to classify the nature of the relationships in the network maps than novice and intermediate programmers. Pathfinder's usefulness for identifying expert-novice distinctions can be interpreted as an indicator that concept ratings reflect conceptual knowledge representations within this knowledge domain.

Pathfinder has also been validated as a measure of conceptual knowledge by contrasting it with definitions of the main concepts in the domain of the history of psychology (Gonzalvo, Canas & Bajo, 1994). For this purpose, college students' knowledge representations of Pathfinder, Multidimensional Scaling (MDS) techniques, and definitions of the main concepts in the history of psychology were compared. Both Pathfinder and MDS students' scores significantly correlated with students' definition scores. These results support the validity of Pathfinder since traditional tests are closer to a definition task than proximity ratings, reflecting a more traditional assessment of college-level knowledge.

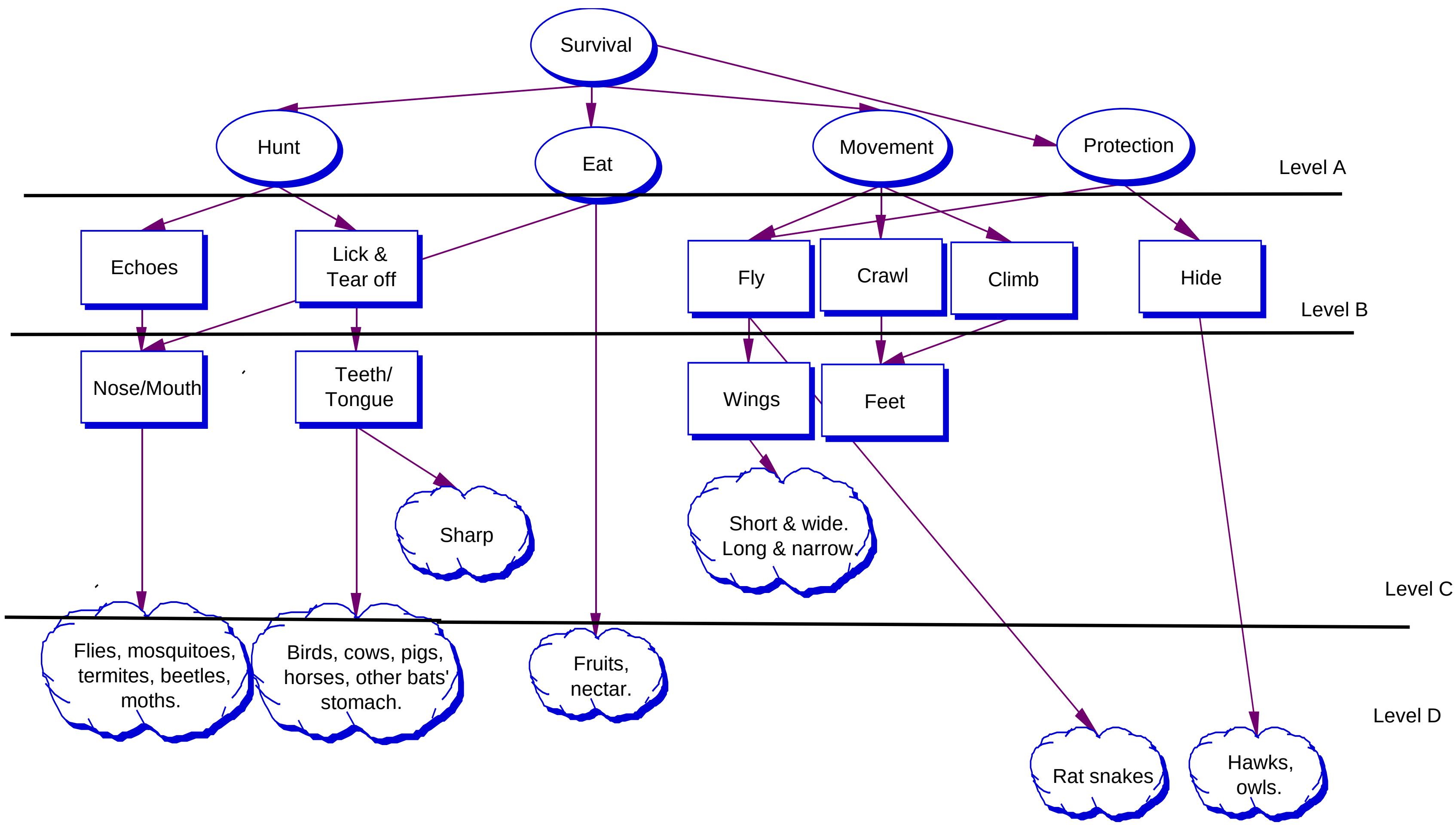
Lastly, validation for Pathfinder as a measure of conceptual understanding is found in the results of this dissertation. It was found that Pathfinder significantly correlated ($p < .01$ and $p < .05$) with an experimenter-designed reading comprehension measure (Multiple Text Comprehension) with high face validity, and with a standardized measure of reading comprehension (Gates-MacGinitie test) for both groups of students in this sample (third and fourth graders). Therefore, in conjunction with measures of reliability (see chapter IV), the correlations of Pathfinder with the two other comprehension measures used, lends support to the validation of Pathfinder as a measure of conceptual knowledge built from text.

Examples of conceptual knowledge representations in ecological science. In the following sections I present two examples of conceptual knowledge representations. The first example presents a concept map and the second example uses a Pathfinder network. In both cases, the representations capture an expert's understanding of a topic in ecological science. Examples are provided with the goal of illustrating experts' conceptual knowledge representations in the knowledge domain of interest in this study. A few words about the features of conceptual knowledge for this study are necessary before presenting this example.

In this investigation, conceptual knowledge learned from text refers to the representation of ecological science concepts and their relationships. As discussed, conceptual knowledge can be represented by semantic networks and mental models. In this study, conceptual knowledge built from text will be measured by instruments that represent both characterizations. Details about each measure of conceptual knowledge built from text will be provided in the Method section. For both characterizations of conceptual knowledge, concepts within the domain of ecology will refer to a class of objects, events, or ideas. Nine ecological science concepts have been defined within the context of this study by experts in this domain. These concepts are reproduction, communication, defense, competition, predation, feeding, locomotion, respiration, and adjustment to habitat (concept definitions are included in Appendix A). Each of these is considered a concept within the domain of ecology because it refers to a variety of behaviors and events that describe interaction with the environment for multiple species. For instance, *defense* refers to a series of behaviors and events that take place for several organisms and species. However, *paws* cannot be characterized as an ecological concept because while it can be related to defense, it is limited to a particular species or organism and particular events or behaviors. In this way, concepts constitute a class of events or behaviors that are inclusive because they are applicable to different groups of organisms and species. At the same time concepts are characterized by their abstractness. This is so because they are "transferable" from organism to organism (i.e., the notion of defense is the same for owls and snakes –defense from predators- but it also implies different behaviors and different features for each of those animals).

A concept map on bats' survival. As an example of a hierarchical representation of conceptual knowledge I will describe a concept map based on an expository text on ecological science content. The text is written at a third- grade level and its topic is bats' survival. It is titled The High Flying Bat and it has 10 illustrations and approximately 300 words. It is organized in five sections: (a) bat survival, (b) hunting and killing, (c) what do bats eat? (d) how do bats move? and (e) how do bats protect themselves? The first section is a brief introduction to the topic of bats and their survival and each of the following four sections contains information on each aspect of bats' survival. Text content has been derived from a variety of expository books appropriate for third-grade students.

In this concept map (see Figure 1), explicit concept-words or phrases from the text and the relationships among these concepts are represented hierarchically by depicting the most inclusive and general concept in the text at the top of the diagram and less abstract concepts in relation to this general concept in lower positions. A concept is defined as a word or phrase that refers to a class of objects, events, or ideas. Therefore, the most inclusive concepts in the map subsume the higher number of objects, events, or


Survival
Hunt
Eat
Movement
Protection
Level A
Echoes
Lick & Tear off
Fly
Crawl
Climb
Hide
Level B
Nose/Mouth
Teeth/ Tongue
Wings
Feet
Sharp
Short & wide. Long & narrow.
Level C
Flies, mosquitoes, termites, beetles, moths.
Birds, cows, pigs, horses, other bats' stomach.
Fruits, nectar.
Level D
Rat snakes
Hawks, owls.

ideas within a given class. A hierarchical form implies that from top to bottom the map gets progressively more specific and less inclusive in the types of relationships represented. Thus, the more levels a concept map has, the higher the degree of differentiation of meaning and conceptual refinement (Novak, 1990; Novak & Musonda, 1991). For instance, on this map, a concept or node such as *survival*, that is higher in abstractness, is depicted at the top of the map. Less abstract concepts, such as *movement* and *protection*, are placed beneath survival. Word-nodes like *nose*, *teeth*, and *wings* are located toward lower sections of the map with the most specific word-nodes, such as types of insects, at the bottom of the map. Most abstract concepts, like survival, are also characterized by their inclusiveness, meaning that the less abstract or more concrete concept-words are encompassed by them and are located below them on the map.

Procedures for node selection for concept maps vary widely. As discussed earlier, one procedure for node selection consists of the identification of salient informational words or sets of words within the text. Each of these content words could be a noun or a verb or a subject or predicate that is semantically central to the content of the text. In line with other representations of conceptual knowledge, when represented in a concept map each of these words or sets of words can be seen as a node in a network of links among various nodes.

In this particular concept map there are 21 nodes distributed across four hierarchical levels. Each level in the concept map expresses a similar level of generality and inclusiveness. Levels in the hierarchy represent, from top to bottom, progressively more specific, less inclusive or less abstract nodes. Nodes represent approximately 8% of the 300 words in the text. Specifically, at the top of the concept map the most abstract node is that of survival. Four nodes are placed directly underneath it: hunt, eat, movement, and protection. Each of these nodes represents ecological concepts that correspond to each section of the text and are placed underneath survival because they are less inclusive than survival and they are conceptually related to it.

Level A represents the basic but central notion that these actions are needed in order to survive and that it is precisely their interrelation that supports survival. For instance, the words *hunt* and *eat* indicate that hunting is necessary for eating and the extent to which the relationship between hunting and eating can be explained depends on what the reader knows about each of those concepts and about their relationship to survival.

As previously discussed, from top to bottom, word-nodes decrease in abstractness and inclusiveness and become more concrete. In this way, Level A links ecological concepts such as hunt, eat, movement, and protection among themselves and links them all to survival. Level B depicts less abstract nodes. These nodes consist of mechanisms needed for survival, i.e., the necessary conditions to fulfill these survival actions, such as move. These conditions are represented by nodes with more concrete and factual information than the concepts in Level A. Thus, if in Level A, a node consisted of the word *move*, at Level B nodes consist of the mechanisms that allow movement for bats such as *flying*, *crawling*, and *climbing.* Level B, therefore, represents nodes and relationships that denote explanations of the ecological concepts at an individual level. Rather than focusing on the relationship among concepts as in Level A, the focus at this level is on the mechanisms, or the "how to", of the concept itself.

The hierarchical relationships between nodes at Levels A and B are evident in that explanations of links at the higher level (A) (i.e., relationships *among* concepts) require knowledge of these concepts in isolation (Level B). In other words, it is only possible to describe how the words *hunt* and *protection* are related and contribute to bat survival if knowledge of how bats hunt *and* how they protect themselves is readily available and interrelated. Thus, increased specificity or concreteness from top to bottom is evident by examining the interrelationships between these two levels in the map. The explanation of a link at Level B is less encompassing, yet necessary, for the explanation of more abstract links at Level A.

At the next lower level (Level C), the map depicts features for the mechanisms described in Level B. Nodes with concrete nouns such as *wings* and *feet* and adjectives such as *long* and *narrow* and *short* and *wide* are included in this level. All of these are descriptive features necessary to explain how bats fly (mechanism in Level B), which in turn serves to explain one instance of the level above, i.e., bats' movement (concept in Level A). Links across all three levels are evident at this stage of construction of the map. Another example of a link from levels A to C would be: Bats *hunt* (concept in Level A) by using *echoes* (mechanism in level B) that they can "hear" by using their *nose* and *mouth* (features in Level C). Therefore, nodes at this Level C constitute physical features of the animal that enable the behavior or mechanisms in Level B to take place. Therefore, at Level C the links represent relationships that are less encompassing and more concrete than those in Level B. If linked to nodes at higher levels, nodes at Level C will serve as supporting details for an elaborate explanation of an ecological concept, i.e., how specific physical features of an organism enable mechanisms or behaviors that define ecological concepts. One such example may be “bats hunt by using echoes that they can hear by using their nose and mouth.”

The lowest level (D) of this concept map presents concrete, factual information in the form of supporting details in a list-like manner. Nodes at Level D constitute a series of items within a category (e.g., *flies, mosquitoes, beetles,* etc.) Information contained in nodes at Level D consists of factual, supporting details that are subordinate to other nodes contained in higher levels in the map. Nodes at Level D are dead-end nodes in the sense that they do not constitute higher or super-ordinate ideas to any other nodes within the map. Rather they are the most concrete and less inclusive nodes in the concept structure. These nodes serve the purpose of providing detailed information that allows for high concept differentiation and precise characterization.

A Pathfinder network on the killer whale. To illustrate another representation of conceptual knowledge an expert Pathfinder network is presented. This network is based on a text segment about killer whales. The text segment was specifically composed for the purposes of illustration of Pathfinder. It has been extracted from an information-trade book on killer whales for the third-grade level titled: “Natural World: Killer Whale.” Two main ecological concepts are included in this text reproduction (or mother-baby interaction) and hunting. The words highlighted in the text correspond to nodes that constitute the Pathfinder network. These words have been specifically selected in relation to the two main ecological concepts. Procedures for selection of these words is briefly explained next.

The Killer Whale

The killer whale is the largest member of the dolphin family. Even though it looks like a fish and lives in the sea, the killer whale is a mammal. To survive, killer whales hunt food in and out of water.

Killer whale babies are born under water near the surface so that both mother and baby can come up for air. Killer whales normally have one calf at a time. The calf can swim as soon as it is born. Mother and baby are always swimming side-by-side touching each other. This makes it much more difficult for large sharks to see the calf when they are on the lookout for food. During the first year, the calf feeds only on its mother's milk. It forms a special feeding tube by holding its tongue against the roof of its mouth. The mother squirts the milk into the tube.

Killer whales hunt for sea animals such as seals, octopus and fish. Sometimes they also eat land animals like the moose or the caribou that come close to the water. Killer whales normally hunt together in family groups. At times they hunt by tipping sleeping seals and penguins into the mouths of other killer whales in the family. They find food underwater by making special clicking sounds. Killer whales listen for the echoes of the clicking sounds that bounce back. The echoes tell them about where the prey is.

Word selection. Bolded words in the text correspond to the seven terms that were selected for the Pathfinder network representation. These words were selected on the basis of their semantic saliency within the text, i.e., the significance they have for the meaning of the text and the two main ecological concepts represented in the text.

Similarity ratings. As previously explained, a Pathfinder network is generated by an algorithm that captures the proximity or similarity ratings among nodes or word-concepts. The Pathfinder algorithm searches through the nodes to find the closest, indirect path between concepts, retaining links in the network that have the minimum length path between two nodes and eliminating spurious links. Similarity or relatedness ratings can be set to different point scales. In this particular example and for the measures used in this study, similarity ratings will be based on a 9-point scale for which three rate points will be available: *least related or non-related* (1); *somewhat or a little bit related* (5) and *most related or very related* (9). Thus, nodes that are not related will be depicted with proximity ratings of 1; nodes that are somewhat or partially related will receive ratings of 5 and nodes that are highly related will have proximity ratings of 9.

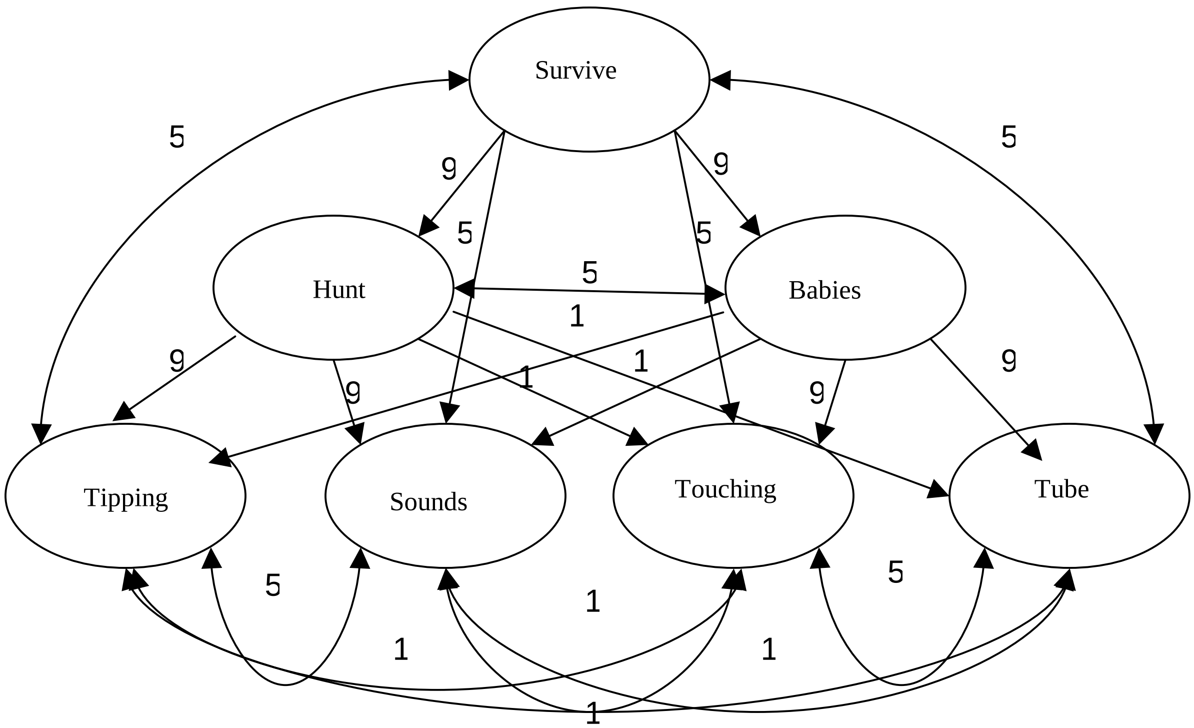


Figure 2. Pattern of proximity ratings for an expert's model representation of the text *The Killer Whale*. Numbers represent similarity ratings for the relationships.

In the diagram for this knowledge network there are six pairs of nodes that are highly related (a rating of 9), seven pairs of nodes that are somewhat related (a rating of 5) and seven pairs of nodes that are not related (a rating of 1). As previously discussed, similarity or proximity ratings between concepts explain relationships among them in terms of their conceptual or semantic proximity. This proximity can be expressed by phrases that convey the meaning of the relationships between those nodes. In the case of highly or closely related terms, relationships can be represented by expressions or phrases such as: *necessary for* (e.g., tipping is necessary for hunting; hunting is necessary for survival; babies are necessary for survival of the species), *depend on* (e.g., babies depend on tubes for feeding and survival) and *characterized by* (e.g., babies are characterized by touching their mothers when they swim). All of these phrases denote the semantic proximity of these nodes rated as highly related.

On the other hand, expressions that represent links between nodes that had been rated as somewhat related (a rating of 5) do not denote the strong interdependency evident in closely proximal nodes. Expressions for these less proximal links could be *contribute to* (e.g., sounds contribute to survival); *sometimes provide(s)* (e.g., touching the mother whale sometimes provides a way of survival); *occasionally co-occur* (e.g., tipping and sounds occasionally co-occur as a way of hunting). Phrases that describe each type of link can serve to contrast differences in proximity ratings between links with ratings 5 and 9.

Even though these are only a few of the phrases that can be used to convey the semantic relationships among these links, a brief perusal of these terms helps to contrast the cognitive or semantic distance between nodes that are closely or highly related and nodes that are somehow related. Lastly, because they represent no relationship among nodes, proximity ratings of 1 cannot be semantically expressed.

To conclude this section I present an example of a Pathfinder network map. If the proximity ratings in the diagram previously presented in Figure 2 were entered into a

Pathfinder proximity matrix, the expert Pathfinder generated network map will look like the one presented below in Figure 3.

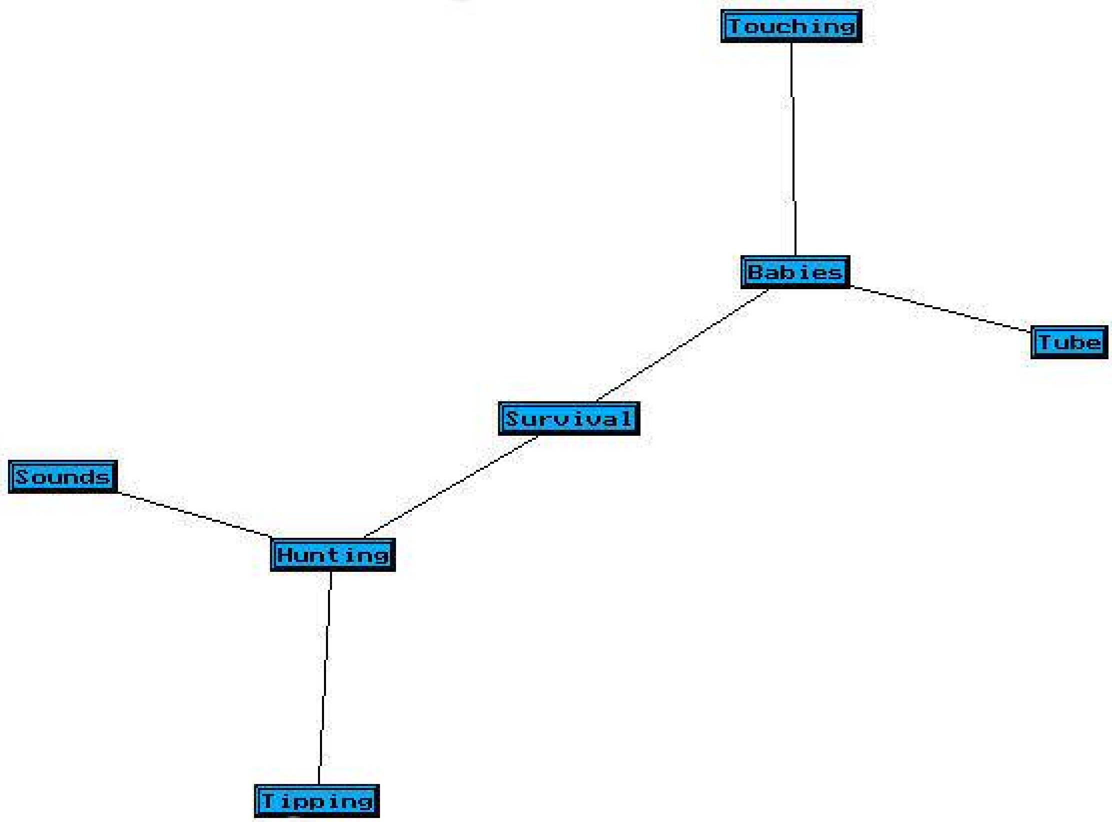


Figure 3. Expert Pathfinder network for the text: The Killer Whale.

Theoretical Expectations and Hypotheses

As it has been discussed in this section of the literature review, conceptual knowledge built from text is defined by a distinct set of concepts with a well-defined set of hierarchical relations among those concepts. Furthermore, successful reading comprehension has been defined in terms of knowledge constructed from text: "When reading is successful, the result is a coherent and usable mental representation of the text. This representation resembles a network, with nodes that depict the individual text elements (e.g., events, facts, setting) and connections that depict the meaningful relations between the elements" (van den Broek & Kremer, 2000, p.2).

The theoretical expectation in this study is that students' questions posed in reference to text will be related to their comprehension of that text. This relationship has been characterized by the association of questions levels with reading comprehension levels being measured as degree of conceptual knowledge built from text. It is expected that students who ask lower-level questions will build lower levels of conceptual knowledge, whereas students who ask higher-level questions will build a higher degree of conceptual knowledge.

If, as it has been purported, students' questions dispose the learner to meaning-making, students who engage in self-generated questioning will be inclined toward active text processing (e.g., Craik and Lockhart, 1972; Singer, 1978; Olson et al., 1985; Raphael & Pearson, 1985; Rosenshine et al., 1996). Active processing of text information implies deeper and more frequent connections to background knowledge, higher number of inferences, and frequent integration of information that leads to knowledge elaborations.

Based on the previous reasoning, it seems sensible to hypothesize that students who ask inferential, conceptual, or deep-processing questions will tend to build knowledge that is commensurate with that type of high-level inquiry. A possible reason behind the association between question levels and degrees of knowledge built from text is related to the process of selective attention previously mentioned. Selective attention was proposed in this literature review as one of the cognitive processes needed for successful questioning. At the same time, selective attention on text information can be seen as a result or a consequence of the impact of questioning on reading comprehension (e.g., van den Broek et al., 2001). By posing a question in relation to a text the questioner needs to focus attention on text information to provide an appropriate answer to the question. Whether text-referenced questions foster attention to specific aspects of the text or attention that is extended to the whole text (see van den Broek et al., 2001 for a review) is a subject for future research. However, under one attention perspective or the other, questions still entail attention to text information that is derived from the intentional learning the question presupposes. In other words, by posing a question about a particular facet of knowledge the intention and expectation to learn about that facet is assumed. Thus, attention to text in order to answer the question will ensue.

Based on these theoretical assumptions about questions and the processes they encompass, it is expected that by asking questions that request a high degree of conceptual integration, students will build knowledge from text that is conceptually integrated. In addition, students who ask lower-level questions that request facts or details rather than conceptual explanations, will tend to build knowledge from text that is commensurate to the basic level request they are posing.

In order to examine these relationships the three hypotheses tested in this dissertation are:

1. Students' question levels on the question hierarchy will be positively associated with students' levels of reading comprehension measured as conceptual knowledge built from text.
2. Students' questions will account for a significant amount of variance in reading comprehension measured as conceptual knowledge built from text when the contribution of prior knowledge to reading comprehension is accounted for.

3. Students’ questions at the lowest levels of the question hierarchy (Level 1) will be associated with reading comprehension in the form of factual knowledge and simple associations. Students’ questions at higher levels in the question hierarchy (Levels 2, 3, and 4) will be associated with reading comprehension consisting of conceptual knowledge supported by factual evidence.

Table 3
Definitions of Terms

Terms	Definitional Statements
Concept	A mental construct, an organizing idea that categorizes a variety of examples that may differ in context but have common attributes (Erickson, 2002). Unit of meaning that captures regularities (similarities and differences), patterns, or relationships among objects, events, and other concepts (Pines, 1986).
Conceptual knowledge	A structured organization of concepts within a topic including their interrelationships and supporting evidence or examples (Guthrie et al., in press).
Conceptual knowledge built from text	A structured organization of concepts containing prior knowledge and new information developed by a reader during interaction with a text.
Mental Models	A mental representation formed as a hierarchy of abstractness and increasing independence from the environment. These could be basic representations such as procedural and perceptual representations or higher-level representations such as verbal narrative and verbal abstract representations (Kintsch, 1998).
Multiple text Comprehension	Reading comprehension measure used in this dissertation consisting of interaction with multiple texts extracted from a variety of authentic ecological science texts for elementary grades. Interaction with texts consisted of question prompts that elicited students' reading and written responses in the form of search logs and comprehension essays.
Passage Comprehension	Reading comprehension measure used in this dissertation consisting of interaction with an animal based passage extracted from a variety of authentic ecological science texts for elementary grades. Interaction with text consisted of students' reading of the passage and a computer task consisting

Table 3 (continued)

Definitions of Terms

Terms	Definitional Statements
	of similarity ratings of text concepts.
Pathfinder networks	A scaling algorithm that transforms a proximity data matrix into a network structure in which each object is represented by a node in the network. The relatedness between the nodes is depicted in the net by how closely they are linked (Goldsmith, Johnson, & Acton, 1991).
Prior knowledge	Knowledge that may be explicit and available to consciousness in order to deal with a particular processing demand (Alexander, Schallert, & Hare, 1991).
Reading Comprehension	The process of simultaneously extracting and constructing meaning through interaction and involvement with written language (Snow, 2002). The construction of a mental representation, a coherent structure by means of identifying and encoding the major parts and relations in a text (e.g., Graesser & Clark, 1985; Kintsch, 1998; Trabasso, Secco, & van den Broek, 1984).
Reading strategies	Procedures that guide students as they attempt to read and write with the purpose of aiding them in their reading (NRP, 2000). Strategies are goal-oriented procedures that are intentionally evoked either prior to, during or after the performance of a reading task (Alexander & Judy, 1988).
Self-explanations	The process of generating explanations to oneself in the context of learning from text, in order to facilitate the integration of new information into existing knowledge (Chi et al., 1994).
Self-generated questions	Questions that are self-initiated and posed by the student in reference to a text, topic or knowledge domain.
Semantic networks	Representations of knowledge used for memory, concept storage and sentence understanding consisting of a set of nodes and links between nodes that indicate inter-node relationships (Groome, 1999). Configurations of related word concepts represented as a set of interlinking nodes that explain word recognition by activation spreading procedures (Sharkey, 1986).

Table 3 (continued)

Definitions of Terms

Terms	Definitional Statements
Student questioning	Process by which students ask or write self-initiated questions about the content of a text before and during reading to help them understand the text and topic.
Question generation	Reading strategy consisting of posing and answering questions about what is being read with the goal of constructing better understating and better memory for text (NRP, 2000).
Questioning hierarchy	A categorization of student generated questions into levels. Levels are defined by the conceptual complexity of the information requested.
Questioning mean	Indicator of performance of student questioning consisting of the average of the hierarchy levels into which a student's questions are coded.
Questioning rubric	Measurement instrument used in this dissertation designed to code and measure elementary school students' self-generated questions in relation to text.
Questioning sum	Indicator of performance of student questioning consisting of the addition of the hierarchy levels into which a student's questions are coded.

Chapter III
Pilot Study

Overview

This pilot study consists of a preliminary investigation of the contributions of student questioning to reading comprehension. The goal of this preliminary study was to test the measures and relationships proposed for the final dissertation. This investigation begins with a theoretical rationale consisting of an abbreviated account of the literature review in student questioning. Next, the same three research hypotheses proposed for the final dissertation are presented. A detailed description of each of the measures used to test the hypotheses is presented next. Most of these measures were the same measures used in the dissertation investigation. After describing the measures, a thorough account of the development and coding procedures for the Questioning and Multiple Text Comprehension tasks are presented. This preliminary investigation concludes with a section on results and a discussion of these.

Contributions of Questioning to Reading Comprehension
A Preliminary Investigation

Theoretical Rationale

Student questioning in relation to text. The process of student question generation in reference to text has been determined to be an important cognitive reading strategy (e.g. Singer, 1978; Rosenshine, Meister, & Chapman, 1996; National Reading Panel, 2000). Asking their own questions in relation to text is an important way for readers to improve their reading comprehension. When students generate questions about material that they read they have to search the text and combine information in order to answer these questions. Spending time searching the text and integrating information helps students comprehend and process what they read more deeply (Rosenshine, Meister, & Chapman, 1996).

Student-initiated questions have also been considered as a valuable learning device that helps students construct meaning and extend text information, as opposed to merely using questions as a way of checking students' recall of text (Beck, McKeown, Sandora, Kucan, & Worthy, 1996). Therefore, teaching students to generate their own questions may be a viable way to support students' reading comprehension and foster an active interaction with text. Active interaction with text takes place as a consequence of having to inspect text, identify ideas, and tie parts of text together in order to answer one's own questions (Craig & Lockhart, 1972). Furthermore, composing questions may require students to play an active, initiating role in the learning process (Collins et al., 1990; King, 1994; Palincsar & Brown, 1984; Singer, 1978) that may not be present when trying to answer questions from other sources, such as text or a teacher's questions.

Student questioning for narrative and expository texts. Evidence of self-generated questions in reference to text has been emphasized in the narrative and expository genres. Within the narrative genre, students' questions have been found to increase understanding and recall of narrative selections (Cohen, 1983; Singer & Donlan, 1982; Nolte & Singer, 1985) and to improve knowledge of story structure as well as comprehension of stories (Singer & Donlan, 1982). Instruction on questions for narrative texts has varied in terms of question form and content of questions. When focusing on question content, instruction has included features such as questions that elicit text explicit information and questions that can be answered by referring to the reader's prior knowledge (Raphael & Pearson, 1985; Ezell, Kohler, Jarzynka, &Strain, 1992).

Instructional interventions have also focused on questions about the main idea of texts. These types of instruction have shown that elementary and middle school students improved their awareness of the main idea of narrative texts (Wong and Jones, 1982) and of expository passages (Palincsar and Brown, 1984) as a result of instruction on self-generated questions. When instruction has focused on question form, a meta-analysis of 27 instructional studies of student-generated questions (for both narrative and expository texts) revealed that instruction in signal words (*who, where, how, why,* etc.) and question stems (e.g., How are X and Y alike? What are the strengths and weaknesses of X? How is X related to Y? What conclusions can be drawn from X?) were the most concrete and effective prompts to use when teaching question-generation (Rosenshine, Meister, & Chapman, 1996).

Unlike the narrative genre for which studies in student questioning are more numerous, empirical evidence in the expository genre is scarcer. However, types of instruction on student questions in the expository genre have contributed to the literature in student questioning by emphasizing question content as the degree of conceptual inquiry of the questions. For instance, different types of instruction have focused on the contrast between literal and inferential types of questions (e.g., Davey & McBride, 1986), "knowledge-based questions" versus "text based questions" (Scardamalia & Bereiter, 1992), and "thought provoking questions" based on question stems (e.g., How is …important? How are …and …similar? What would happen if…? Why is …better than…?) (King & Rosenshine, 1992). The student population in these studies consisted of elementary and middle school students. Common to all of these types of instruction is the attempt to have students differentiate between questions requiring literal text information from questions requiring integration from different text sources, and complex or causal explanations utilizing the student's prior knowledge (e.g., Scardamalia & Bereiter, 1992). Students who received these two latter types of questioning instruction asked higher numbers of questions that focused on explanations rather than on facts, and asked more text integration (i.e., across sentences) and inference-type questions than students who did not receive this instruction. In some of these interventions, students who were taught to ask inferential, integration, and "knowledge based" questions showed better reading comprehension results than to students who had been taught to ask questions that required literal or explicit text information (e.g., King, & Rosenshine, 1992).

Student questioning in science domains. Conceptual content of questions has been particularly emphasized as part of questioning instruction linked to the process of science inquiry. Such is the case of seventh-graders who were taught to ask different questions levels (e.g., lowest level: factual questions; highest level: cause-effect relationships) in order to evaluate them in relation to the research process in science (Cuccio-Schirripa & Steiner, 2000). High level or conceptual types of questions were defined as "researchable" or meaningful questions. These questions had to request conceptual information in the form of causal explanations. Students who asked higher level, researchable questions improved in their ability to ask questions that focused on cause-effect relationships (Cuccio-Schirripa & Steiner, 2000).

Questioning levels and conceptual knowledge built from text. Overall, instruction on self-generated questions in relation to both narrative and expository texts, has emphasized the positive impact that self-generated questions have on students' understanding of text, as well as on the students' ability to formulate new questions. When student questioning has taken place within science instruction, questions have been distinguished in terms of the types of knowledge or learning processes that they endorse. Therefore, studies in this area underscore both the importance of teaching students to formulate their own questions in order to foster an inquisitive attitude, as well as the cognitive benefits that questioning has for reading comprehension and science learning.

However, despite their contributions to the understanding of student questioning these instructional studies have not provided qualitative characteristics of students' questions so as to describe students' competence in asking questions in reference to text. In particular, questions have not been described in terms of a hierarchy of conceptual complexity that can be related to text-comprehension. In other words, what research in student self-generated questions has not documented are data explaining the relationship between types of questions and reading comprehension. This relationship could be examined by categorizing questions into a hierarchy of conceptual complexity that relates levels of questions to degrees of reading comprehension.

In this study, I propose a question hierarchy in which question types are distinguished into four levels according to the conceptual complexity of their inquiries. Higher or lower question complexity is defined by the knowledge content the question requests. In general, lower-level questions are characterized by inquiries about factual knowledge or simple *yes/no* answers. Higher-level questions, on the other hand, request information that needs to be organized at a conceptual level. Using this categorization of questions I propose to examine the relationship between quality of questions, defined by question levels, and levels of reading comprehension, defined by degrees of conceptual knowledge built from text.

Conceptual knowledge has been defined as knowledge of the interrelationships among concepts in a network, with appropriate supporting evidence for those concepts and their relationships (e.g., Alao & Guthrie, 1999; Chi et al., 1994). In this investigation, conceptual knowledge is described in a range from relatively low conceptual knowledge to high conceptual knowledge in the domain of ecological science. As it has been the case with other knowledge domains such as geology (e.g., Champagne, Klopfer, Desena, & Squires 1981), high conceptual knowledge in this investigation is characterized by experts' representations of knowledge in the domain of ecological science. In this way, experts' representations are utilized as standard knowledge structures against which students' knowledge representations can be judged (for a review see Champagne et al., 1981).

Method

Hypotheses

In view of the proposed relationship between student self-generated questions and degree of conceptual knowledge built form text, three research hypotheses are considered.

1. Students' question levels on the question hierarchy will be positively associated with students' level of text comprehension as measured by a Multiple Text Comprehension task and a Passage Comprehension task.
2. Students' questions will account for a significant amount of variance in reading comprehension, measured by a Multiple Text Comprehension task and a Passage Comprehension task when the contribution of prior knowledge to reading comprehension is accounted for.
3. Students' questions at the lowest levels of the question hierarchy (Level 1) will be associated with reading comprehension levels, as measured by a Passage Comprehension task, in the form of factual knowledge and simple associations. Students' questions at higher levels in the question hierarchy (Levels 2, 3 and 4) will be associated with reading comprehension levels, as measured by a Passage Comprehension task, consisting of factual and conceptual knowledge.

Design

Data for this study were drawn from an investigation of reading comprehension among 400 students in Grade 3 in four elementary schools in a small city in a mid-Atlantic state. The data for this pilot study consisted of assessment data collected in December 2001. Assessment tasks included prior knowledge, questioning, and reading comprehension tasks, which were relevant to this pilot study. Data for this sample were collected on the following tasks: Warm-up, Prior Knowledge, Multiple Text Comprehension, Questioning for Multiple Text Comprehension, Questioning for Passage Comprehension, and Passage Comprehension. The larger investigation, from which data for this pilot study were drawn, examines the effects of reading instruction on reading, motivation, and science across two different instructional interventions (Guthrie, Wigfield, & Barbosa, 2000).

Participants

A total of 196 third-grade students from four elementary schools in a small city in a mid-Atlantic state participated in this study. Each school had a multicultural population including approximately 74% Caucasian, 21% African American, and 3% Asian. These proportions are typical of the district as a whole, which had 87% Caucasian, 8 % African American, 2% Asian, and 2% Hispanic. On the indicator of poverty, the four schools in the sample had approximately 20% of students qualifying for free and reduced-price meals. On this indicator the district had 13%, showing comparability between the sample and the district population. All four schools had approximately the same number of boys and girls, which resembled the district as a whole in which 50 % were boys and 50 % were girls. Parental permissions to participate in the study were obtained. Third-grade classrooms in all schools were self-contained, with the teacher providing the instruction for approximately 25 children.

To analyze questioning scores the sample was reduced approximately to 50%, thereby coding 100 students' tasks for questioning. Further reduction of the sample occurred due to students' absences while the tasks were administered. This provided a sample of approximately 70 third-grade students for hypothesis testing.

Materials

All reading tasks and reading materials were constructed in the domain of ecological science. Two types of texts were used in this study. Three alternative forms of a multiple text packet containing topics on two given biomes and the animal and plant life in them were developed. Forms for this packet were: Oceans and Forests (form A); Ponds and Deserts (form B), and Rivers and Grasslands (form C). Accompanying these packets, three sets of pictures (forms) illustrating one of the biomes corresponding to the biome set for each form were developed.

The second text consisted of a shorter text passage on an animal's survival. The three alternative forms for this passage were: The High Flying Bat (form A); The Incredible Polar Bear (form B), and The Scary Shark (form C). For clarity, from here onwards, I will refer to the packets on biomes as "multiple text", and to the shorter text about an animal as the "animal passage". I have briefly described these two types of texts in an earlier section (Attributes of Expository Text) in Chapter II of this dissertation. I will elaborate on that description next.

The multiple text packet focuses on characteristics of two biomes and life of animals and organisms living in them. The three alternative forms are parallel in content difficulty and text structure. Each packet is composed of 22 chapter-like sections, 16 of which are relevant sections to the topic of the packet and 6 of which are distracters (or non-relevant sections). Content emphasis in all three forms was balanced across sections. This was achieved by having the number of sections that covered characteristics of each of the biomes equal to the number of sections that focused on the animals that inhabited them.

The six irrelevant sections (or distracters) included animals that were highly improbable to be found in any of the pertinent biomes (e.g., a section on polar bears in the Rivers and Grasslands packet) or topics on biomes that bore no relationship to the biomes in the packet (e.g., a section on rainforest climates in the Rivers and Grasslands packet).

In addition to the 22 sections, each packet had a two page Glossary containing 44 words and a one-page Index. The 22 sections were distributed across approximately 75 pages, with a length of three to four pages per section.

Text difficulty was also equally distributed throughout the sections in the packet. There were two levels of text: easy and difficult. Of the 16 relevant sections, 8 sections were made up of easy text and 8 sections contained difficult text. The six non-relevant sections were also divided into three sections of easy text and three sections of difficult text. Text difficulty varied mainly in terms of sentence length. Easy text had approximately 3 to 13 words per sentence, whereas hard text had approximately 14 to 28 words per sentence. Additionally, text difficulty was differentiated by paragraph length and number of paragraphs per section. Easy text spanned an average of two to four sentences per paragraph and five to six paragraphs per section. Difficult text had an average of 6 to 10 sentences per paragraph and 13 to 16 paragraphs per section. There was a minimum of one illustration per page, with the majority of these in black and white and 11 color illustrations. The same number and distribution of illustrations were found in all three forms of the packet. Text and illustrations were extracted from a variety of second-to fifth grade trade books.

The animal passage focused on four ecological concepts that described the animal's survival. All three alternative forms of the animal passage were parallel in content and text organization. Text in the passage was organized by starting with a short introductory paragraph of no more than five sentences consisting of a brief description of the animal and a short list of its survival mechanisms. The rest of the text content was organized into four sections describing four ecological concepts. The four ecological concepts described were very similar in all three forms: eating/feeding, hunting/killing, movement/locomotion, and reproduction or protection from the environment (only one of these last two was included in a given form). Headings for each of the four ecological concepts preceded each section.

The text was four pages long with two to three paragraphs per page, and about 100 words per page. Sentence length was 7 to 14 words. There were approximately 10 black and white illustrations per packet (with a minimum of two and a maximum of four illustrations per page) with captions accompanying some of the illustrations. Number and distribution of these illustrations were the same in all three forms. Text and illustrations were extracted from a variety of second-to fifth grade trade books.

Measures

A set of six tasks (Warm-up; Prior Knowledge; Multiple Text Comprehension; Questioning for Multiple Text Comprehension; Questioning for Passage Comprehension and Passage Comprehension) was administered to the students over four school days.

For the Warm Up Task the students used the biome pictures. For two of the tasks (i.e., Multiple Text Comprehension and Questioning for Multiple Text Comprehension) students used the multiple-text packet. The animal passage was used for the tasks of

Questioning for Passage Comprehension and Passage Comprehension. Directions were read by the classroom teacher for all tasks, with the exception of the Questioning for Passage Comprehension and Passage Comprehension tasks. Directions for these tasks were read by a trained graduate student in the school's computer lab. Students were randomly assigned to any one of the three alternative topics/forms.

Warm-up task. The students' first activity was to warm-up to the reading and writing tasks in pairs by observing and discussing a picture related to the topic. Each 5 by 7 inch color picture illustrated one of the two biomes in each biome set: a picture of grassland for Grasslands and Rivers, a picture of a forest for Oceans and Forests, and a picture of a desert for Ponds and Deserts. Each picture contained the main animals found in that particular biome. Animals were depicted interacting with each other or with the plants belonging to that biome. Teachers read the following instructions to the students: " With your partner, look at the picture below. Talk about everything you see in the picture. You do not have to write anything. Just discuss the picture with your partner. You have 5 minutes to discuss your observations."

Students discussed the picture in pairs for five minutes. The teacher collected the pictures after the five minutes.

Prior knowledge. To assess prior knowledge students individually wrote their prior knowledge on the biomes they had previously observed and discussed in the Warm Up task. Directions were as follows:

> In the space below, write what you know about (e.g., Grasslands and Rivers). When writing your answer, think about the following questions. How are (grasslands and rivers) different? What animals and plants live in a (river)? What

> animals and plants live in a (grassland)? How do these animals and plants live? How do the plants and animals help each other live? Write what you know. Write in complete sentences. You have 15 minutes to write your answer.

The teacher read the directions aloud to the students. After 7 minutes, the teacher provided the following prompt "You are doing well. Keep writing if you can. You can turn over the page if you need more room." After 15 minutes, the teacher collected the forms.

Multiple text comprehension. This task was administered over three sessions during three school days. On the first day, students spent approximately 10 minutes on the task. On the second and third day, students spent a maximum of 40 and 30 minutes respectively on the task. During the first two sessions students independently searched for information and read the multiple text packets. Students also took notes on their reading while the text was available to them. During the third session, students wrote about what they had learned during their interaction with text in the two previous sessions.

In the first two sessions, note-taking was structured so that students were able to write the information found for different sections in the packets and label them accordingly. The teacher helped the students understand the task by guiding them through an example. The teacher read the following form-directions to the students:

> Use this packet to learn about (grasslands and rivers). Read to answer these questions. How are (grasslands and rivers) different? What animals and plants live in a (river)? What animals and plants live in a (grassland)? How do these animals and plants live? How do the plants and animals help each other live? Later you will be asked to write what you have learned from this packet. Some of the

sections of this packet will be helpful and some will not. Choose the sections that will help you explain how animals and plants live in (grasslands and rivers). Write the letter of the section you choose to read. Read the sections for as long as you want in order to answer the questions. Write down what you have learned on the lines provided.

Example

Now, let's try an example together. Look at the table of contents in your packet. Suppose you choose to read section M. Write the letter of that section in the blank beside the word *Section*. Now read Section M for five minutes and write down what you learned from that section.

Below these directions the form read: "Section___, What I learned" for the students to complete the example with the teacher's help.

There were 10 section with spaces for students to write. After the example, directions read: "Continue to read and write in order to explain how plants and animals live in (grasslands and rivers)." Students completed this task in two days. On the first day, students completed the example and two of the 10 sections. Students stopped after completing two sections or after 10 minutes, whichever came first. On the second day, students worked for a total of 40 minutes on this task. Once again, the teachers read the first paragraph of the directions. After 7 minutes, teachers prompted students by saying; "You are working hard. Keep reading and learning about (grasslands and rivers)." A second prompt was given after 20 minutes by saying; "You are learning a lot. Good work. There is more information for you to find. Continue to read in order to explain how plants and animals live in (grasslands and rivers)." Students stopped after completing all ten sections or after 40 minutes. On average, students completed approximately six sections relevant to the topic.

During the third and last session of this task, students were encouraged to go over the notes they had taken during the previous sessions. The teacher stated, "Look at your notes to remember what you learned." After reviewing their notes for five minutes, students' notes were collected and the teacher read the directions for the students' writing:

> In the space below, describe (grasslands and rivers). In writing your answer, think about the following questions. How are (grasslands and rivers) different? What animals and plants live in a (river)? What animals and plants live in a (grassland)? How do these animals and plants live? How do the plants and animals help each other live? Use science ideas in your writing. Write in complete sentences. You have 25 minutes to write your answer.

The teacher provided two prompts to the students during their writing by saying: "You are doing well. Keep writing. You can turn over your page if you need more room." Students' writing was collected after 25 minutes.

Questioning for multiple text comprehension. Students spent a total of 15 minutes on this task. The multiple text reading packets were distributed to students. Students were instructed to browse the packets while the next form was distributed. Students received the questioning form and were told to close their packets so the text was not available to them while asking questions. The teacher read the directions on the form:

> You have been learning about (grasslands and rivers). What questions do you have about (grasslands and rivers)? These questions should be important and they

should help you learn more about (grasslands and rivers). You should write as many good questions as you can. You have 15 minutes.

Students were provided enough space to write a maximum of 10 questions. Students could write more than 10 questions, but these additional questions were not included for coding purposes.

Questioning for passage comprehension. Students spent approximately 7 minutes on the Questioning for Passage Comprehension task. A trained graduate student administered this task and the Passage Comprehension task. Using the animal passage for this task, the students were encouraged to read the title together and to browse the passage silently for 2 minutes. After browsing, the students were instructed to “Write as many good questions about the (animal) as you can.” Students wrote the questions on a provided question form. Text was not available to students while they were writing questions. A maximum of four question-spaces were provided. Students were permitted to write more questions if they chose to do so, but these were not included in the coding process. After 5 minutes, question forms were collected and the administrator read directions for the Passage Comprehension task to the students.

Passage comprehension. As a second indicator of reading comprehension students were given the task of independently rating the similarity of words extracted from the animal passage. Students were randomly assigned to one of three alternative forms of the animal passage: The High Flying Bat, The Incredible Polar Bear, or The Scary Shark. Students spent approximately 30 minutes on this task. Directions were: “Now, read the animal passage again. Look for big ideas, important relationships, and important facts. Please remember these big ideas, important relationships, and important facts. You have 5 minutes."

After reading the text, students were directed to a proximity-ratings example sheet. On this sheet three examples were provided. For each example, a pair of words to be related on a scale from 1 to 9 were presented. Students were guided through each of these examples and helped to explain the similarity, or lack thereof, between each pair of words. At this time the rating values for each example were discussed. Three rating values were utilized: 1, 5, and 9. A rating value of 9 was equivalent to words being "very related", a value of 5 was equivalent to words being "a little bit related" and a value of 1 implied words were "not related at all." Students were guided through the examples by the administrator until it was clear that they understood the task. To facilitate students' understanding of the task, the graphics on the rating sheet were identical to the graphics on the computer screen. Directions for the students were as follows:

> Now you will show what you have learned from the packet. We will use the computer to do this. Write your name on the top of the sheet called Rating Sheet. Flip the sheet over to see the practice sheet. (Practice sheet is held up for all to see).
>
> On your paper is an example. What words do you see at the top of the page? (Students are asked to point to each word on the paper-elephant, bird, flying). How do you think these words are related?
>
> *Are bird and flying very related?* (Student's response)
>
> Yes, a bird likes to fly. You would give those words that are very related a 9. Circle the 9 on your paper.

Are elephant and flying related? (Student's response)

No, I've never seen a real elephant fly, have you? You would give those words a 1 because they are not related. Circle the 1 on your paper.

Are elephant and bird related? (Have students' provide the answer that these are different size but they are both animals)

Yes, they are both animals, however, they are a bit different. A score of 5 goes to words that are a little bit related. Circle the 5 on your paper.

After the examples all the students understood that the number 9 meant that word-pairs were "very related", the number 1 meant that words were "not at all related" and a the number 5 meant that word-pairs were "a little bit related".

Directions proceeded indicating that the students were going to do the same activity on the computer. Nine words were selected from each form of the packet for the students to rate their relatedness. Words were selected by experts in the field of ecology. Word selection was based on the assumption that the words represented the conceptual knowledge structure of the text. Before beginning the task individually, the students were asked to read aloud from the computer monitor the words that would form part of the task. The sequence of appearance of word pairs on the screen varied across students, however all students worked with same word pairs. This facilitated students working individually. Text was not available to the students while rating the words. Directions continued as follows:

Hit the space bar to see your first words. You may not have the same words as your neighbor. This is OK. Look at your words and decide how related they are. Press a 9 if they are very related, press 1 if they are not at all related, press 5 if they are a little bit related. You can change your number by pressing a different number. Once you are sure of your number press the space bar. The new words will appear. Decide how they are related. Then press the space bar. Do the rest of the words.

After 10 minutes, students were instructed to raise their hands when the screen read "STOP."

Administrative Procedures

All six tasks were administered during 4 days in the first week of December 2001. Teachers were present during this administration and intervened only if behavioral problems arose. The students were told that they would be taking some tests and that these tests would help teachers and some researchers learn about their reading. Administration time varied from 20 to 40 minutes each day, depending on the sequence of task/s for the day. The administration sequence over the 4 days was as follows:

- Day 1: Warm-up; Prior Knowledge and Multiple Text Comprehension (Session 1)
- Day 2: Multiple Text Comprehension (Session 2) and Questioning for Multiple Text Comprehension
- Day 3: Multiple Text Comprehension (Session 3)
- Day 4: Questioning for Passage Comprehension and Passage Comprehension

As it was described, the Multiple Text Comprehension task was divided into three sessions over 3 days. This was done to alleviate cognitive and attentional demand from the students. Teachers were familiarized with the administration sequence and the directions one week in advance of the testing week. Teachers were specifically told that they could answer students' questions about directions, but that they should refrain from answering students' questions on text or assessment content. If students finished before the allotted time, they were told to read a book or rest their heads on their desk for a few minutes. If the administration of tasks for the day lasted more than 25 minutes, students were given a 5-minute break.

Coding Questions in Relation to Text

Developing a question hierarchy. The question hierarchy presented in this dissertation was constructed to investigate children's levels and growth in questioning. This hierarchy was used to categorize students' questions in two questioning tasks (Questioning for Multiple Text Comprehension and Questioning for Passage Comprehension). Based on students' written questions we (the author and another investigator) constructed a hierarchy characterizing the types of questions students asked.

To build the question hierarchy, we started by examining third grade students' questions at the beginning of the school- year. Students' questions were examined in two stages; first, questions for the Questioning for Passage Comprehension task (questions about animals) and second, questions for the Multiple Text Comprehension task (questions about biomes). We sorted 65 questions from a sample of 25 students holistically into six relatively lower and higher categories. We then identified the critical qualities of each category and discussed them. To test our prior classifications we sorted another set of 40 questions into the same categories. We discussed the categories again and reduced them to four categories, based on redundant characteristics across the six original ones.

After reasonable agreement on the four categories we identified two question prototypes for each category. Questions at Level 1 consisted of a request for factual information or a factual proposition. These questions had to be simple in form and request a simple answer such as a single fact, or refer to a relatively trivial, non-defining characteristic of organisms (plants and animals), ecological concepts, or biomes. Example prototypes of these questions are: How big are sharks? or How much do bears weigh? Answers to these low level questions generally consist of a yes/no or a one-word answer.

At Level 2, questions request a global statement about an ecological concept or an important aspect of survival. The qualitative distinction between Level 1 questions and Level 2 questions rests on the conceptual (rather than factual) focus that the latter questions have. A concept is an abstraction that refers to a class of objects, events or interactions (Guthrie & Scafiddi, in press). For example, in the realm of ecological science, an inquiry about the number of stripes on zebras is a request for factual information, however competition among zebras to find food or mates in the grasslands constitutes a request for conceptual information. This is so because competition constitutes a class of interactions or events (e.g., with other animals, in different circumstances) that removes the request from the concrete or the particular as a question for factual information would. Competition constitutes a concept because its class reference (e.g., set of behaviors, interactions with the environment) allows it to be transferable to other species or organisms. Despite its conceptual focus, questions at Level 2 still are global in their requests for information, without specification about aspects of the ecological concept. The answers to Level 2 questions may be simple or moderately complex descriptions of an animal's behavior or physical characteristics. Prototypes for questions at Level 2 are: How do sharks mate? or How do birds fly?

An answer to questions at Level 2 may also be a set of distinctions necessary to account for all the forms of species or to distinguish a species' habitat or biome. For example: What kinds of sharks are in the ocean? What kinds of algae are in the ocean? Again, rather than a request for a mere grouping or quantification of organisms the notion of class or group is evident in these questions.

Level 3 questions request an elaborate explanation about a specific aspect of an ecological concept with accompanying evidence. To qualify as Level 3, these questions must be higher in conceptual complexity than questions at Level 2. Higher conceptual complexity was evident within the questions themselves because these questions probed the ecological concept by using knowledge about survival or animal characteristics. Prototype questions at this level showed clear evidence of specific prior knowledge about an ecological concept that was contained in the question itself: e.g., Why do sharks eat things that bleed? Why do elf owls make homes in cactuses? Knowledge about sharks' eating habits and elf owls' habitats was necessary to formulate these questions. Each question requests information about an ecological concept (i.e., feeding/eating; adaptation to habitat) while specifying a particular aspect of that concept.

It is possible to contend that answers to Level 3 questions can be readily found because they are explicitly written in the text. However, even if this is the case, the assumption behind this hierarchy is that the student asking a Level 3 question is capable of a conceptual elaboration that is beyond the literal information in the text. The generation of a Level 3 question implies a request for information that is highly conceptual in and of itself. In other words, although it is feasible that a Level 3 question could be answered by literal text information, its formulation must incorporate a statement of knowledge *within* the question, a feature that would require high-level thinking.

Lastly, questions at Level 4 were characterized by inquiries about the interrelationship of ecological concepts or by interdependencies of organisms within or across biomes. Questions at Level 4 were differentiated from the other three levels because they constituted a request for principled understanding with evidence for complex interactions among multiple concepts and possibly across biomes. At this level, interactions between two or more concepts are central to the requests for information. Prototypes for this level are: Do snakes use their fangs to kill their enemies as well as to poison their prey? Do polar bears hunt seals to eat or feed their babies? For questions to qualify as Level 4, the request for information must be focused on a relationship among ecological concepts that compares or contrasts these in relation to one particular organism or in reference to more than one organism.

Once these four categories and their prototypes were agreed upon, another sample of 65 questions from 25 students were coded independently by the two investigators based on the definitions and prototypes. Codings were compared and discussed. The descriptive statements were refined sufficiently to represent the new data. Discussions continued until the two raters concurred on the definitions and the prototypes for each category.   In particular, changes consisted of refinements and additions to each of the four levels so as to encompass categories of questions formulated for the text on biomes.

Questions about biomes fit into the same four levels that questions on the topic of animals had been sorted into. Previously agreed definitions for each level applied to the questions on biomes due to the fact that they shared the same definitional characteristics, namely: Factual Information (Level 1), Simple Description (Level 2), Complex Explanation (Level 3), and Pattern of Relationships (Level 4). However, it was observed that questions that inquired about characteristics of biomes, as opposed to the features of the organisms living in them, required further differentiation. It was necessary to distinguish these questions into categories that differentiated them according to their conceptual content. Questions in these categories were differentiated on the basis of "commonplace or peripheral characteristics of a biome" versus "specific or defining attributes of a biome."Defining attributes of biomes consisted of biome features that were included within the definitions of each of the biomes. Biomes definitions were extracted from several sources in ecological science and summarized by experts in the field of ecology (biome definitions are included at the end of the Questioning Hierarchy in Appendix B).

Therefore, higher conceptual complexity for questions about biomes was characterized by its closeness to essential or defining attributes of a biome. Questions that have this conceptual complexity would inquire about essential attributes of a biome, rather than request peripheral or trite aspects of a biome. In this way, a Level 1 question about a biome inquires about commonplace or general features of the biome that are not considered as defining attributes of the biome, for example, How deep are rivers? (i.e., depth is not a defining attribute of a river). On the other hand, a Level 2 question about biomes requests information that involves or makes reference to a defining attribute of a biome. Prototypes for this level are: Why does it never rain in the desert? (i.e., reference to the defining attribute of dryness) or Why are grasslands so dry? Both questions request an explanation on defining features of each of the biomes: dryness or lack of precipitation.

Level 3 questions about biomes would utilize a defining attribute of a biome (or make implicit reference to it) in order to ask about a complex characteristic of the biome in relation to its defining attribute. A prototype example is: Can you dig a water hole in the desert? The complex characteristic that the question asks is related to the possibility of finding water in a dry environment (i.e., defining attribute of dryness). Additionally, questions about biomes at Level 3 inquire about the effects or the influence a defining feature of a biome has on life in the biome, for example: How do animals in the desert survive long periods without water? (i.e., effects of a drought on desert animals). In the same way that Level 3 questions about animals probe for information about a specific aspect of an ecological concept for a given animal, Level 3 questions about biomes probe for information about specific attributes of a biome.

Level 4 questions about biomes request information about relationships between the organisms and the biomes they live in. These relationships are explicitly expressed within the questions and can take two forms: (a) The question requests a description of an organism's ecological concept in reference to the organism's biome (or biomes), for example, Why do salmon go to the sea to mate and lay eggs in the river? or (b) the question inquires about an explanation of the interaction of two biomes in relation to an organism's or a group's survival, for example: How does the grassland help the animals in the river? In the same way that Level 4 questions about animals inquire about the interaction of ecological concepts, Level 4 questions about biomes inquire about relationships and interactions among organisms and biomes.

Interrater agreement for the question hierarchy. To examine interrater agreement for the question hierarchy, two independent raters were trained about the levels of the hierarchy. The first rater, an independent undergraduate student, rated students' questions asked during the Questioning for Multiple Text Comprehension task (multiple text packet), as well as questions for the Questioning for Passage Comprehension task (animal passage). Training consisted of having the independent rater become familiar with the question hierarchy, as well as code 30 questions for five students for which the rater and the principal investigator coded questions independently. Coded questions were compared and discussed. Once both raters agreed upon answers, the independent rater proceeded to code 73 questions for 11 students. Interrater agreements were 96% for adjacent and 92% for exact coding into these categories for a total of 103 questions.

The same procedure was followed with the second rater, an independent graduate student, with the exception that interrater agreement was established for questions separately for each type of text. A sample of 250 questions for 25 students was used for this procedure. The rater was first trained according to the level definitions and prototypes. Second, the rater coded questions for 10 students (for both types of texts) and results were discussed with the principal investigator. Once the raters agreed upon answers, the independent rater proceeded to code the questions for the 15 remaining students. Interrater agreements were 92 % for adjacent and 84 % for exact coding into these categories for the animal passage (82 questions) and 96 % adjacent and 76 % exact agreement for questions on the multiple text (168 questions).

Scores for questioning. Questions were coded into the hierarchy (Levels 1-4). A student's score on the question hierarchy was based on two indicators: questioning sum and questioning mean. The sum was constructed to represent the students' combination of quantity of questions simultaneously with the quality of their questions. This was equivalent to the addition of the on-hierarchy levels to which each question was coded. The sum indicator was calculated by adding the scores assigned to the question levels for each codable question. Questions that could not be coded according to the hierarchy levels were scored 0. Thus, these questions did not contribute to the questioning sum. The mean was computed to represent the average quality (hierarchy level) of the questions asked. The questioning mean was computed by dividing the sum indicator by the number of questions asked. The number of questions asked included the non-codable questions (coded 0). Thus, the non-codable questions were included in the computation of the mean indicator. I used both indices of questioning competence in the analyses for this investigation.

Final Questioning Hierarchy. The final question hierarchy for texts in ecological science is presented in Appendix B. An abbreviated version of the Questioning Hierarchy is presented next:

Table 4

Questioning Hierarchy

Level	Question Characterization
Factual Information-Level 1	Request for a factual proposition. Question asks relatively trivial, non-defining characteristics of organisms or biomes, e.g., How much do bears weigh? Question is simple in form and requests a simple answer such as a fact or a yes/no type of answer, e.g., Are sharks mammals?
Simple Description-Level 2	Request for a global statement about an ecological concept or a set of distinctions to account for all forms of a species, e.g., How do sharks mate? Question may also inquire about defining attributes of biomes, e.g., How come it always rains in the rainforest? Question may be simple, but answer may contain multiple facts and generalizations.
Complex Explanation-Level 3	Request for elaborated explanations about a specific aspect of an ecological concept, e.g., Why do sharks sink when they stop swimming? Question may also use defining features of biomes to probe for the influence those attributes have on life in the biome, e.g., How do animals in the desert survive long periods without water? Question is complex and answer requires general principles with supporting evidence about ecological concepts.
Patterns of Relationships-Level 4	Request for elaborated explanations of interrelationships among ecological concepts, interactions across different biomes or interdependencies of organisms, e.g., Do snakes use their fangs to kill their enemies as well as poison their prey? Question displays science knowledge coherently expressed within the question. Answer may consist of a complex network of two or more concepts, e.g., Is the polar bear at the top of the food chain?

Coding Multiple Text Comprehension Responses

Reading comprehension: Developing a hierarchy for conceptual knowledge. To investigate students' levels of reading comprehension a hierarchy for conceptual knowledge was developed. This hierarchy was utilized to examine students' writing about their learning from information texts in the in the Multiple Text Comprehension task (Guthrie & Scafiddi, in press). To build this hierarchy, 25 students' written compositions were initially sorted into five comparatively higher and lower clusters. Next, qualities that discriminated between the clusters were established. Because some of the students' responses were highly conceptual and did not fit into the five categories, a sixth category was created to capture the complexity of the highest conceptual responses. Differences in the qualities of each category were based on the organization of students' responses. In general, lower-level responses were shorter, with Levels 1 and 2 being the shortest, and higher-level responses tended to be longer, with Levels 5 and 6 being the longest for the majority of the students. Even though length of writing was a good surface indicator for discriminating among levels, content organization was the major discriminator among lower and higher levels in the hierarchy, with the highestlevel responses having higher organization than the lower levels. Higher organization was evident by students' responses that included two to four ecological concepts and a few interconnections between the concepts that were concisely explained. Lowest levels of organization tended to list isolated facts or attributes (i.e., facts about animals or biomes) with minimal, if any, connections among each other. Next, I describe the levels of the hierarchy following closely the characterization by Guthrie and Scafiddi (in press). The examples from third grade students' writings are the same examples used by these authors.

Facts and Associations: Simple- Level 1. A student's writing consists of a few characteristics of a biome, a single classification of an organism in the biome, or a list of organisms living in the biomes. The statements at this level are list-like and do not include biome definitions or descriptions of ecological concepts. Two examples of Level

1 statements are: “In grasslands lions, tigers, zebras.” “There are fish, grass, bear, deer, snake, otter, flowers, and trees.” In the first example, three organisms are classified into the biome they inhabit and the biome is explicitly mentioned, whereas in the second example a longer list of organisms is provided but the biome is not included.

Statements at this level contrast biomes by mentioning the presence of a feature or a particular organism in one of the biomes and the absence of it in the other biome. An example of this is: “In oceans there are no trees. In forests there are not octopuses. Octopuses live in oceans. Foxes live in forests.” In this example, oceans and forests are differentiated from each other by the presence or absence of trees and octopi. Although, the statements represent true facts, the biomes are not defined by a set of defining features, but rather by non-essential characteristics.

Facts and Associations: Extended – Level 2. Statements at this level are characterized by factual information that appears in form of a list of several organisms classified into a specific biome. Different from Level 1, this level is characterized as “extended” because the statements encompass several (five or more) organisms that are correctly classified into a biome. These multiple classifications can be accompanied by general biomes’ descriptions and/or a weakly stated ecological concept. The following is a Level 2 example:

> In forests there are more animals. For example there are deer, birds, snakes, lizards, bugs, rats, squirrels, chipmunks, and alligators. In oceans there are fewer animals. There are whales, dolphins, sea lions, fish, sharks and other animals from the sea.

Nine organisms are accurately classified for the forest and five animals are classified for the ocean. Although knowledge reveals accuracy in the categorization of animals and plants a global, biome description is not yet present.

However, Guthrie and Scafiddi (in press) highlight that typical of Level 2 statements are multiple classifications with a limited biome definition, along with a weakly stated concept. An example would be:

> An animal that lives in a grassland is an elephant. Another animal that lives in grassland is a giraffe. An animal that lives in grassland is a zebra. A plant that is in a grassland is grass. Another plant is trees. Also bushes are in grassland. An animal that lives in a river is the water boatmen. Also some fish and seaweed live in rivers. Grasslands are different because rivers are wet and grasslands are dry. Plants help animals live so animals can eat.

Biome descriptions, in this example, are limited because they do not provide extended features of the biomes but only minimal detail about the defining physical characteristics of both biomes (Guthrie & Scafiddi, in press). Different from Level 1, where the biomes were distinguished by the contrasting the absence of organisms in one or the other, biomes at this level are distinguished from each other by at least one defining aspect (e.g., “grasslands as dry and the rivers as wet.”), The ecological concept of *feeding* is present, although weakly stated (e.g., “Plants help animals live so animals can eat.”).

Concepts and Evidence: Simple – Level 3. Statements at this level contain an elaborate definition of both biomes. These statements may also present one or more ecological concepts with minimal supporting information (Guthrie & Scafiddi, in press).

Different from Level 2, where biome definitions were limited, biomes in Level 3 statements are presented in a more accurate fashion with supporting information in the form of facts and patterns. These statements also contain correctly classified organisms into the biomes. However, the statements are disorganized in the presentation of information.

The following is a Level 3 example:

> I know that all deserts are not hot and dry. Some are cold, icy, and fog hides them. Ponds and desert are different because deserts are miles long and ponds are not miles long. Ponds and deserts are also different because of where they are located. I know that diving beetles and damselflies live near and in ponds. I know that it hardly any animals or plants live in the hot and dry deserts. Ponds and deserts are the same because some desserts have ice and water just like when it is winter and ponds turn into ice and the water is in the pond is underneath. Ponds and desserts *(sic)* are also the same because animals live in both deserts and ponds. I also know that Angelfish and piranhas live in ponds. The plants that live in ponds are seaweed, algae, moss. Ponds and desserts are the same because snakes live in the desert and snakes can also live in ponds.

Biomes in this statement are defined and contrasted in terms of several characteristics: temperature, size, location, types of animals, etc. Information is no longer presented in a list-like manner but in relation to aspects of survival and biome features. However, although concepts are briefly stated (e.g., "…hardly any animals live in the hot and dry deserts", adjustment to habitat) there is minimal supporting information and the overall organization of information is weak.

Concepts and Evidence: Extended – Level 4. Statements at this level are characterized by conceptual understanding revealed in the description of ecological concepts. Concepts are illustrated by the behavioral patterns and the physical features of organisms. Organisms are described in terms of their survival mechanisms and behaviors. Furthermore, higher-level principles, such as food webs or interrelationships among ecological concepts may be partially stated (Guthrie & Scafiddi, in press).

The following is an example of a Level 4 statement:

> Some snakes, which live in the desert, squeeze their prey to death and then eat them. This is called a deadly hug. Bright markings on some snakes are warnings to stay away. In the desert two male jackrabbits fight for a female. Some deserts are actually cold and rocky. Both deserts' hot or cold, it barely ever rain and if it does it comes down so fast and so hard it just runs off and does not sink into the ground.

Although briefly stated, conceptual understanding is revealed by the five ecological concepts presented. These concepts are: predation, feeding, defense (defensive markings) communication (the warning communicated by the markings), and competition (among jack rabbits). Also essential biome information about deserts is provided by stating that deserts can be icy, not just hot, and that a lack of rain is characteristic of both cold and hot deserts.

Patterns of Relationships: Simple – Level 5. Essential to this level are the interactions between different organisms and their biomes. An example of a Level 5 follows:

A river is different from grassland because a river is body of water and grassland is land.

> A river is fast flowing. Grasshoppers live in grasslands. A grasshopper called a locust lays its egg in a thin case. One case could carry 100 eggs. The largest herbivores in the grassland are an elephant *(sic).* In the African savanna meat-eats prey on grazing animals, such as zebra *(sic).* Many animals live in grasslands. The river is a home to many animals. In just a drop of river water millions of animals can be living in it. Many fish live in the river. Many birds fly above the grasslands and rivers. A river is called freshwater because it has no salt in it.

Conceptual understanding is reflected by the parallel between the organisms that inhabit these biomes (Guthrie & Scafiddi, in press). After the two biomes are briefly defined, the focus of the statement shifts to the animals inhabiting them. Rather than presenting information in a factual manner, animals are described in terms of ecological concepts. For example, the locust, a specific type of grasshopper in the grassland, is described in terms of its reproduction and supporting information for the concept is provided (i.e., details about the egg case).

The parallel between the diverse organisms that live in the same biome is given by introducing the largest herbivore in grasslands, the elephant, after describing a small insect such as the locust (Guthrie & Scafiddi, in press). Other ecological concepts such as predation are also discussed although with minimal supporting information (e.g., predation of the zebra in the savanna). The organization of the statement can be noticed in the parallel description of the animals that inhabit the second biome, the river.

Patterns of Relationships: Extended – Level 6. Well-supported principles of ecology are fundamental components of these statements. These principles are characterized by relationships among multiple organisms and their habitats. The concepts presented are supported by statements that link the concepts to organisms' behaviors or physical adaptations. An example of a Level 6 follows:

> River and grassland are alike and different. Rivers have lots of aquatic animals. Grasslands have mammals and birds. Rivers don't have many plants but grassland have trees and lots of grass. Rivers have lots of animal like fish trout and stickle backs. They also have insects and mammals, like the giant water bug and river otters. Grasslands usually have lions, zebras, giraffes, antelope, gazelles, and birds. In rivers the food chain starts with a snail. Insects and small animals eat the snail. Then fish eat the small animals and insects. Then bigger animals like the heron and bears eat the fish. Snails also eat algae with grows form the sun. In the grass lands the sun grown the grass. Animals like gazelle, antelope, and zebra eat the grass.Then animals like lions eat them. This is called a food chain of what eats what. In a way the animals are helping each other live. Animals have special things for uses. Otters have closable noses and ears. Gills let fish breath under water. Some fish lay thousands of egg because lot of animals like eating fish eggs. Some animals have camouflage. Swallow tail butter fly larva look like bird droppings. That is what I know and about grasslands rivers.

The organization of the overall essay is evident in the systematic way in which information is presented. The essay starts with a general statement about the differences and similarities for the two biomes. Next, information that elaborates on this broad statement is presented. This information, consisting of the different organisms living in each biome, is presented in an orderly fashion (i.e., rivers first, grasslands next).

Evidence of ecological principles is found in the two food chains presented. The first food chain describes the organisms in a river, with a snail as a prey and insects as the snail's predator. The student then presents a fish as a predator of insects and a prey for bigger animals. As Guthrie and Scafiddi (in press) pointed out, this sequence in the chain shows that the student recognizes that a single organism is capable of being both a predator and prey. This understanding of the principle behind the food chain is also evident in the statement concluding the description of the grassland chain (i.e., "This is called a food chain of what eats what"). Conceptual understanding is further revealed in the notion that by engaging in these prey-predator behaviors these animals are contributing to a cycle of survival (i.e., "In a way the animals are helping each other survive"). In addition to the description of the food chain, conceptual understanding is also evident in the supporting information provided to explain other concepts such as respiration (e.g. "Otters have closable noses and ears. Gills let fish breath under water."). "This knowledge structure contains multiple food chains in two biomes interconnected and characterized by core ecological concepts that are amply illustrated. We observed only very few grade 3 students at this level". (Guthrie & Scafiddi, in press).

Characteristics of the knowledge hierarchy. This hierarchy is comparable to the rubric constructed by Chi et al. (1994), which represented conceptual knowledge of the circulatory system. Like Chi et al.'s hierarchy, higher levels in this rubric represent higher levels of conceptual knowledge characterized by qualitative and quantitative shifts with respect to lower knowledge levels. In particular, the progress from Level 2 to Level 3 is seen in the improvement from representing several "facts" in text to representing a few major "concepts" from the text. This is a qualitative change because it is more than the addition of more propositions to a simpler statement. Likewise, the progress from Level 4 to Level 5 is seen in the representation of concepts in isolation (Level 4) to the formation of complex patterns (Level 5) (Guthrie & Scafiddi, in press). Complex patterns imply coherently organized relationships among concepts that are supported by factual details. In Chi et al.'s (1994) rubric these relationships are expressed in terms of higher, "systemic knowledge" of the human circulatory system. In the conceptual knowledge hierarchy, higher knowledge is represented by explanations of complex relationships among multiple organisms and their habitats. In both rubrics, higher knowledge is represented by well-supported explanations of the essential relationships in the topic. As well, in both hierarchies, higher knowledge assumes superordinate concepts, supported by subordinate information in a structured network of knowledge.

Interrater agreement for the conceptual knowledge hierarchy. To examine interrater agreement for the knowledge hierarchy, two, independent raters were trained according to the levels of the hierarchy. Both raters, an independent undergraduate (first rater) and an independent graduate student (second rater), rated 16 students' essays according to the level definitions and prototypes. First, both raters coded five students' essays according to the levels in the hierarchy. After results were discussed and answers were agreed upon, the independent raters proceeded to code the essays for the 11 remaining students. Interrater agreements were 100% for adjacent (minus or plus a level) and 81% for exact coding into the hierarchy levels for the first rater and 100% and 82% respectively for the second rater.

Scores for conceptual knowledge. Students' essays in the Multiple Text Comprehension task were coded to the hierarchy levels. The same knowledge hierarchy was used to score students' responses in the prior knowledge task.

Final conceptual knowledge hierarchy. A complete version of this hierarchy is included in Appendix C. An abbreviated version of the knowledge hierarchy is presented next.

Table 5

Conceptual Knowledge Hierarchy

Level	Level Characterization
Facts and associations – simple. Level 1	Students present a few characteristics of a biome or an organism.
Facts and associations – extended. Level 2	Students correctly classify several organisms, often in lists, with limited definitions.
Concepts and evidence – simple. Level 3	Students present well-formed definitions of biomes with many organisms correctly classified accompanied by one or two simple concepts with minimal supporting evidence.
Concepts and evidence – extended. Level 4	Students display several concepts of survival illustrated by specific organisms with their physical characteristics and behavioral patterns.
Patterns of relationships – simple. Level 5	Students convey knowledge of relationships among concepts of survival supported by descriptions of multiple organisms and their habitats.
Patterns of relationships – extended. Level 6	Students show complex relationships among concepts of survival emphasizing interdependence among organisms.

Coding Passage Comprehension Responses

Passage comprehension scoring. This task assessed comprehension by assessing the conceptual knowledge structure that students generate based on similarity ratings of word pairs. Students rated the relatedness or similarity of nine words (36 word-pairs) based on a point scale of 1 (non-related), 5 (somewhat/ a little bit related) and 9 (very related). Students' relatedness ratings were analyzed by computing a correlation between each student and an expert's model score of relatedness ratings (Johnson, Goldsmith, & Teague, 1994). The Pathfinder computer program performs this computation by correlating (Pearson r) pair-wise ratings between each student and the expert. Thus, each student's 36 ratings were correlated to the expert's ratings. Correlation scores ranged from –1 to +1.

Graphic representations based on the relatedness ratings are also generated by the computer program. A graphic network displays the connection among nodes based on the students' ratings. These network maps represent the knowledge structure of the rater visually. In this way, network maps which, represent the lowest end of the correlation range (e.g., around .1 to around .2), represent no clustering of concepts and only some basic understanding of the relatedness between some words. Higher correlations (.3 to .5) represent increasing connections between concepts with clustering of the main word concepts and related supporting words linked to these. Generally, these networks represent a loose clustering of two main concepts with words connected to them. Higher or lower correlations within this range (.3 to .5) are partially dependent on whether these connected words are scattered in the map or if they are clustered in connection to each of the two concepts. At the highest end of the correlation range (correlations around .6 and .7), networks depict clusters of words consisting of a main concept and most, or all, of the supporting words for each of the main concepts. Additionally, these higher-level maps show a hierarchical organization that includes main concepts subordinate to an overarching or super-ordinate concept (Davis, Guthrie, & Scafiddi, submitted 2002).

To illustrate the differences among levels of knowledge organization, I present students' examples of four levels of network maps. Each of these maps represents a graphic organization of knowledge based on students' reading of a passage on polar bears. The passage is titled "The Incredible Polar Bear" and it is a Grade 3 reading level. It consists of four pages and is organized around five sections: survival, eating, hunting, locomotion, protection from the environment. The super-ordinate ecological concept in this text is *survival*, and the subordinate concepts to survival are *protect* and *move*. Supporting factual words for the ecological concept of protection are: *fat*, *den*, *shed*, and supporting words for the concept of movement are: *paddle, steer* and *webbed*.

Following the students' example maps (Figures 4 to 7), I include an expert's map (Figure 8) for this same passage. In this map the two main concepts are shown as linked to the supporting facts in two separate clusters. These clusters are in turn, subordinate to the super-ordinate concept of survival, which is located in the center of the map to depict the hierarchical organization of the overall map. When compared to the rest of the maps, the hierarchical organization of this map shows that knowledge is conceptually organized. The Pathfinder network maps presented here are from Davis, Guthrie, & Scafiddi, (submitted 2002).

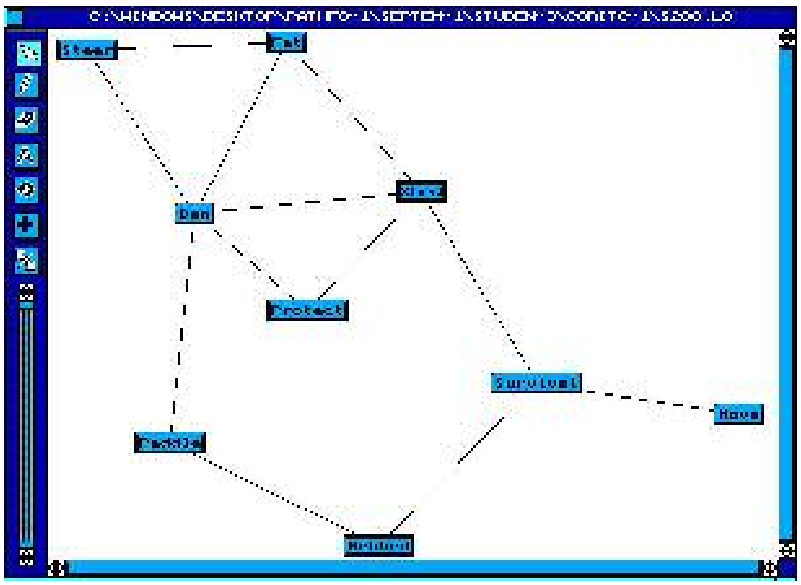


Figure 4. Pathfinder network map for Level 1 (correlation = around .1)

The map at Level 1 is characterized by no clustering of the subordinate concepts (*protect* and *move*), which denotes the lack of overall organization. However, basic knowledge of relations between some of the words is shown (e.g. *survival* and *move*). In this example, the student knew that *paddle* and *webbed* were related but did not associate these words with move. As well, even though *move* and *survival* are connected, *move* is not connected to any other words.

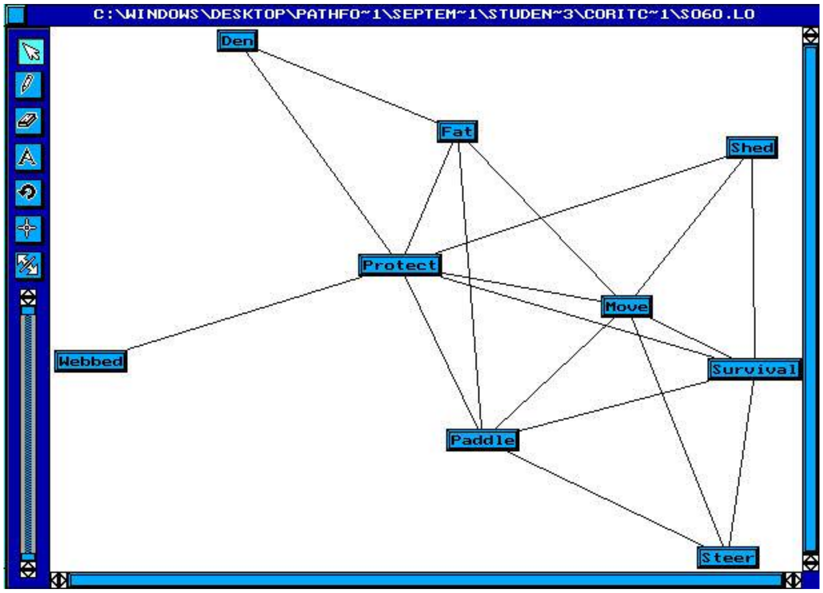


Figure 5. *Pathfinder network map for Level 4 (correlation = around .4)*

Even though the clustering of the concepts in Level 4 maps is hard to notice, there is some initial clustering by connecting *survival* to *move* and to *protect*. Furthermore, these latter concepts are connected to supporting facts (e.g. *den* and *fat* are connected to *protect*). However, some of these words are wrongly connected (e.g. *protect* and *webbed*, and *fat* and *paddle*). These wrong connections denote misconceptions that reveal the lack of overall conceptual organization and accuracy.

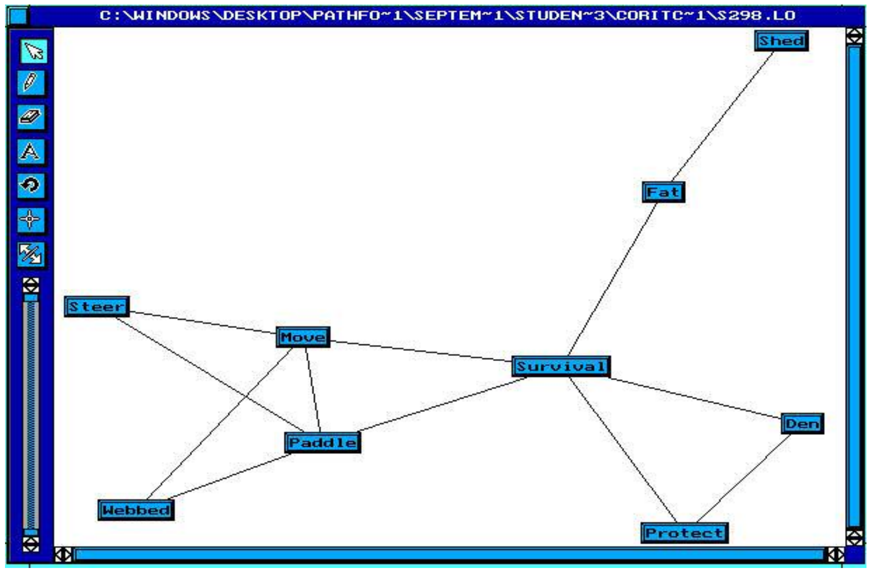


Figure 6. Pathfinder network map for Level 6 (correlation = around .6)

At Level 6, the map shows a clear clustering of the two main subordinate concepts, *move* and *protect*, with *survival* in the middle of the map connected to each of them. Also, each of the concepts is connected at least to one supporting word (e.g., *protect* is connected to *den* and *move* is connected to *paddle*, *webbed* and *steer*). However, of the two main subordinate concepts, only *move* shows a clear cluster of connected words, whereas *protect* is only connected to *den*, but is not connected to the other two supporting words (i.e. *fat* and *shed*).

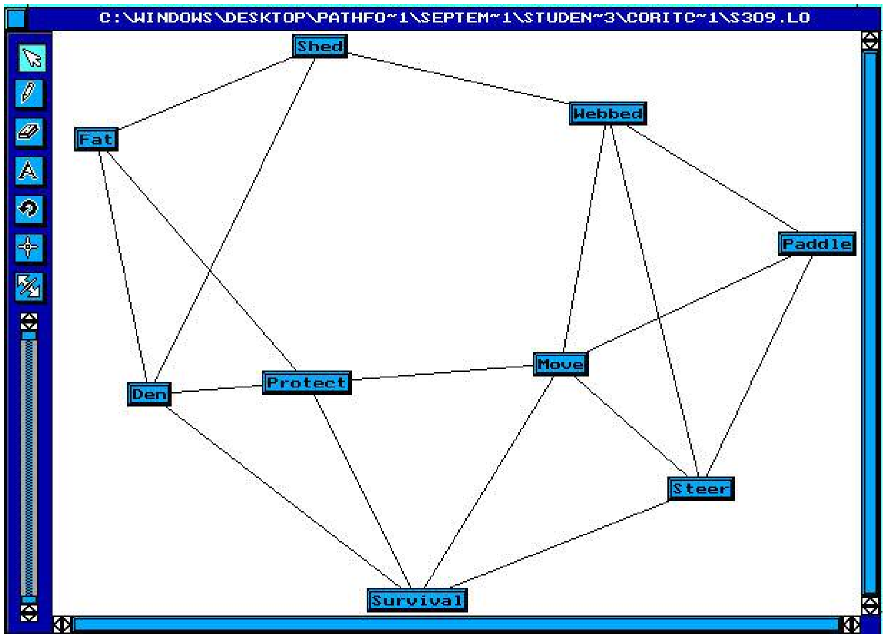


Figure 7. *Pathfinder network map for Level 7 (correlation = around .7)*

At Level 7, the hierarchical overall organization of the concepts is shown in a clearer clustering of the concepts. Survival is located towards the middle of the map and it is connected to both subordinate concepts. One of the concepts (move) has all three supporting words connected to it. However the second subordinated concept (protect) is connected to two of its supporting words (fat, den) but it is only indirectly connected to the other supporting word (shed) through another supporting word (i.e., den). This indirect connection may be one of the factors influencing the fact that the correlational level of the overall map, although very high, is not higher.

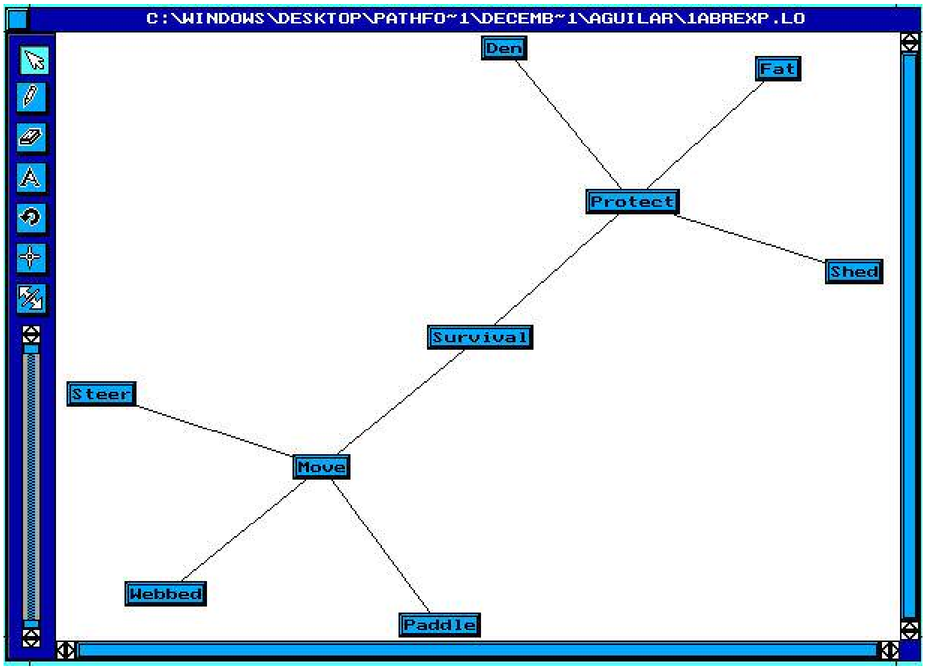


Figure 8**.** Pathfinder network map for an expert's knowledge representation.

Observation of these network maps helps to visually capture the different levels of conceptual knowledge organization. Lower levels of knowledge organization depict inappropriate connections among words that denote a lack of hierarchical organization of concepts. Absence of word clusters characterizes these maps. Higher levels of structural organization of knowledge are characterized by maps that show word clusters depicting the appropriate connections among words. Finally, in the expert map, word clusters are themselves displayed as subordinate to the super-ordinate concept in the passage, thus showing a hierarchical organization of knowledge.

Results

The Questioning for Multiple Text Comprehension task was composed of 10 question-items and the Cronbach's alpha coefficient for this task was .80. The Questioning for Passage Comprehension task included 4 question-items and Cronbach's alpha for this task was .37. Because internal consistency estimates are, among other factors, a function of the number of test items, it is highly probable that the low number of items in this task had an impact on its reliability coefficient.

Initial construct validity for the question hierarchy was calculated by correlating the mean student scores on the hierarchy for the two questioning tasks. The mean score (or average value) of the questions asked is assumed to represent the average level of question quality based on the hierarchy categories. Question quality was associated across tasks with a validity coefficient of .27, $p < .05$. This initial association of the quality of questions (i.e., similar question levels asked) over two tasks and three different topics might be indicative of initial construct validity for the question hierarchy.

Concurrent validity for the Passage Comprehension task was supported by the association between the two reading comprehension tasks. The correlation of scores between the Passage Comprehension task and the Multiple Text Comprehension task, a more traditional measure of reading comprehension, was .58, $p < .01$. Additionally, internal consistency reliability estimates for this task were established for each of its alternative forms. Cronbach alpha coefficients were: for the Incredible Polar Bear: 88, for The Scary Shark: .87, and for The High Flying Bat: .85. For clarity purposes results are reported separately for each of the three hypotheses presented.

Hypothesis 1. Students' question levels on the question hierarchy will be positively associated with students' level of text comprehension as measured by the Multiple Text Comprehension task and the Passage Comprehension task.

This hypothesis was examined by correlating the cognitive variables of reading comprehension, questioning, and prior knowledge. Two measures of reading comprehension were used in these analyses, so two sets of correlations are presented. First, the variables of multiple text comprehension, questioning for multiple text comprehension, and prior knowledge were correlated (Table 6). Second, passage comprehension, questioning for passage comprehension, and prior knowledge were correlated (Table 7). Two indicators for the questioning variable were utilized in these analyses: questioning sum and questioning mean. The questioning sum represents the addition of the levels of the questions asked. The questioning mean consists of the average level of the questions asked. Table 6 shows correlations among the variables of Multiple Text Comprehension, Questioning for Multiple Text Comprehension task (both indicators), and prior knowledge. This table shows that the correlation between questioning and reading comprehension on the topic of biomes was .28, ($p < .05$) for the questioning sum indicator and .04 for the mean indicator. The correlation between multiple text comprehension and prior knowledge was .25 ($p < .05$). Prior knowledge also correlated with the questioning sum indicator, .28 ($p < .05$).

Hypothesis 1 was also supported by the correlations for the shorter, animal passage. Table 7 shows correlations among the variables of Passage Comprehension, questioning on the topic of animals, measured by the Questioning for Passage Comprehension task, and prior knowledge. This table shows that both questioning indicators correlated significantly with passage comprehension. Questioning sum correlated with passage comprehension at .24 ($p < .05$) and questioning mean correlated with Passage Comprehension at .23, ($p < .05$). This confirmed the findings for the Multiple Comprehension task shown in Table 1 for the sum indicator for the questioning variable. The correlation between prior knowledge and passage comprehension was .23

($p < .05$). For each set of analyses, there were 153 students and missing data were handled by using pair-wise deletion.

Table 6

Intercorrelations between Multiple Text Comprehension, Questioning for Multiple Text Comprehension (topic of biomes) and Prior Knowledge

Task	*1*	*2*	*3*	*4*
1. Multiple Text Comprehension	__	.285*	.041	.246*
2. Questioning Sum for Multiple Text Comprehension		__	.489**	.278*
3. Questioning Mean for Multiple Text Comprehension			__	.028
4. Prior Knowledge				__

Note: * $p < .05$, ** $p < .01$

Table 7

Intercorrelations between Passage Comprehension, Questioning for Passage Comprehension (topic of animals) and Prior Knowledge

Task	1	2	3	4
1. Passage Comprehension	__	.235 *	.231*	.225*
2. Questioning Sum for Passage Comprehension		__	.484**	.090
3. Questioning Mean for Passage Comprehension			__	.088
4. Prior Knowledge				__

Note: * $p < .05$, ** $p < .01$

Hypothesis 2. Students' questioning will account for a significant amount of variance in reading comprehension, measured by a Multiple Text Comprehension task and a Passage Comprehension task, when the contribution of prior knowledge to reading comprehension is accounted for.

To examine this hypothesis, I first conducted a multiple regression with passage comprehension as the dependent variable. The independent variables were prior knowledge and questioning for passage comprehension. In this analysis, prior knowledge was entered first and questioning was entered second. Results of this analysis are shown in Tables 8 and 9. Tables 8 and 9 differ in that the indicator for questioning is questioning sum in Table 8 and questioning mean in Table 9.

In Table 8, questioning using the questioning sum indicator accounted for a significant proportion of variance in passage comprehension, as is evident by the significance of the increment of variance associated with this variable. Questioning had an R of .31 with a change in R^2 of .06, which was significant ($F = 4.88$, $df = 70$, $p < .05$). The proportion of variance accounted for by prior knowledge was not statistically significant. This lends support to the hypothesis that questioning accounts for variance in reading comprehension even when variance attributable to prior knowledge is accounted for. As shown in Table 9, when the mean was the indicator of questioning, none of the variables had a statistically significant effect on passage comprehension.

Table 8

Summary of Hierarchical Regression Analysis for Variables Predicting Passage Reading Comprehension

Variable	***R***	R^2	*ChaR*^{2}	*FCha*	*p*<
Prior Knowledge	.19	.03	.03	2.58	.11
Questioning Sum for Passage Comprehension	.31	.09	.06	4.88	.03

Table 9

Summary of Hierarchical Regression Analysis for Variables Predicting Passage Reading Comprehension

Variable	*R*	R^2	*ChaR*^{2}	*FCha*	*p*<
Prior Knowledge	.19	.03	.03	2.58	.11
Questioning Mean for Passage Comprehension	.27	.07	.04	2.83	.09

Hypothesis 2 was also tested with a different measure of comprehension (the Multiple Text Comprehension task) as the dependent variable in a multiple regression. Independent variables were prior knowledge and questioning for the Multiple Text Comprehension task. Results of this analysis are shown in Table 10. The analysis shows that both prior knowledge and questioning for multiple text comprehension accounted for a significant proportion of variance in reading comprehension, as is evident by the significance of the change in variance associated with each variable. Prior knowledge had an *R* of .25 ($F = 4.45$, $df = 69$, $p < .05$). However, when questioning was entered, the *R* was .33, and the R^2 change was .05, which was statistically significant ($F = 3.88$, $df = 68$, $p < .05$). Questioning accounted for variance in reading comprehension when variance attributable to prior knowledge was accounted for.

Table 10

Summary of Hierarchical Regression Analysis for Variables Predicting Multiple Text Comprehension

Variable	***R***	R^2	*Cha*R^2	*FCha*	*p*<
Prior Knowledge	.25	.06	.06	4.45	.038
Questioning Sum for Multiple Text Comprehension	.33	.11	.05	3.88	.053

Hypothesis 3. Students' questions at the lowest levels of the question hierarchy (Level 1) will be associated with reading comprehension levels, as measured by the Passage Comprehension task in the form of factual knowledge. Students' questions at higher levels in the question hierarchy (Levels 2, 3, and 4) will be associated with reading comprehension levels, as measured by the Passage Comprehension task, consisting of factual and conceptual knowledge.

Support for this hypothesis was found in the relationship between levels of questions and levels of passage reading comprehension as measured by Pathfinder. In order to examine this relationship, scores for questions and reading comprehension on the Passage Comprehension task were examined. Question levels were grouped into two categories, low and high questions. Low questions consisted of questions that reflected factual knowledge. These questions corresponded to an average value (mean for the questions asked) lower than the lowest level of conceptual questions in the question hierarchy (i.e., Level 2). High-level questions consisted of questions that reflected conceptual and factual knowledge. These questions corresponded to Levels 2, 3, and 4 in the question hierarchy and they were categorized as corresponding to an average value equal to or higher than 2. To obtain this cutoff value the mean for the questioning mean variable was calculated. The distribution was divided into two categories: scores below the mean (Mean=2) corresponded to the category of low questions and scores equal to or above the mean corresponded to the high questions category. For this sample, this latter category included mainly Level 2 and Level 3 questions and only approximately 1% of Level 4 questions.

Students who asked low-level questions (Level 1) performed at levels of passage comprehension that corresponded to correlation scores of around .4 as generated by Pathfinder. On the other hand, students who on average asked conceptual questions (Levels 2, 3 and 4) had levels of passage comprehension that corresponded to correlation scores of around .6 to .7. These correspondences are shown in Figure 9.

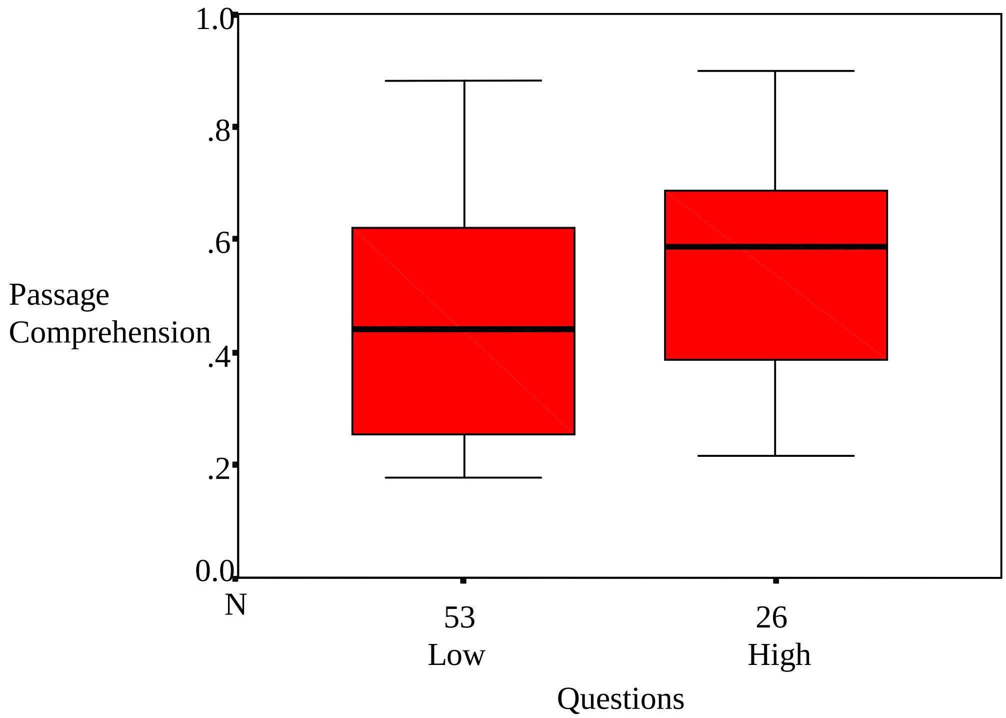


Figure 9. Association between question levels and passage comprehension levels.

Discussion

My major purpose in this preliminary investigation was to examine the relationship between student self-generated questions and their reading comprehension. The first step towards this account was to document the relationship between reading comprehension and questioning in relation to text. Results for hypothesis 1 have supported this association that has been previously explored both in the narrative (e.g. Singer & Donlan, 1982; Cohen, 1983; Nolte & Singer, 1985; Palincsar & Brown, 1984) and expository genres (e.g. McGregor, 1988; Davey & MacBride, 1986; Scardamalia & Bereiter, 1992; Cuccio-Schirripa & Steiner, 2000). What these results add to this literature is the documentation of the association of questioning levels and reading comprehension scores, measured as conceptual knowledge built from text. Student generated questions have not previously been categorized into hierarchical levels that characterize questions on the basis of their conceptual content in relation to text and correlated statistically to a quantified measure of reading comprehension. Therefore, the first step in this investigation was to document this association by examining levels of reading comprehension and question levels.

Results supported the association between reading comprehension and students' questions in relation to text across two reading comprehension tasks and two questioning tasks, even when controlling for the background variable of prior knowledge. For the multiple text questioning task students asked questions about biomes and the organisms living in them. Only the questioning sum indicator correlated significantly with reading comprehension. This indicator represented the additive value of all questions asked, thus it was assumed to be an indicator of both number and quality of questions. Its correlation with reading comprehension for both questioning tasks may be indicative that it is both the quantity and quality of questions asked that can be associated with reading comprehension levels.

To understand further the effects of questioning on reading comprehension, I examined the effects of prior knowledge on questioning and reading comprehension. Prior knowledge has been previously taken into account when studying students' questions (Miyake & Norman, 1979; Scardamalia & Bereiter, 1982; van der Meij, 1990; Ezell et al., 1992), however it has not always been examined as a potentially confounding variable. These results showed that when students' reading comprehension was measured in the same knowledge domain (i.e., ecology), but in a different topic within that domain (i.e., an animal's survival versus life in two biomes) other than prior knowledge, students' questioning contributed significantly to students' performance in reading comprehension, whereas prior knowledge did not. Once again, of the two questioning indicators used (questioning sum and questioning mean) only the sum indicator contributed significantly to explain performance in passage reading comprehension. As previously contended, this may be due to the fact that the sum is a better indicator of this variable since it captures both the quantity and quality of the questions asked. Further research needs to explore this possibility.

There is a plausible explanation for the absence of a relationship between prior knowledge and reading comprehension. It is possible that prior knowledge did not account for any significant amount of variance in passage reading comprehension because the Prior Knowledge task used in this pilot study assessed knowledge in the domain of ecological science (knowledge of biomes and organisms living in it), whereas the Passage Comprehension task focused on the specific topic of animals' survival within this knowledge domain. Even though both tasks share the same domain of ecological science, the absence of variance accounted for by prior knowledge in passage reading comprehension may be attributable to the disparity in scope between a broader knowledge domain and a task focused on a specific topic.

To better account for the relationship among prior knowledge, questioning, and reading comprehension a second hierarchical regression analysis was run. In this analysis, reading comprehension was measured as comprehension of multiple texts on biome` characteristics and animals that inhabited those biomes. Students' prior knowledge and questioning were measured in the same topic. As expected, and confirming the previous analysis, students' questions about biomes and their animals contributed significantly to students' reading comprehension and understanding of this topic, even when the contribution of students' prior knowledge on the topic was taken into account. These results seem to indicate that students' questions are related to and can partially explain students' reading comprehension within a topic, even when students' prior knowledge about that topic is accounted for.

Furthermore, considering that for this sample, measures used for students' reading comprehension were based on three different texts for three different sets of biomes, the contribution of questioning to reading comprehension not only supports previous results, but serves to explain that student questioning is not artifact of a particular knowledge topic and probably nor of particular knowledge domain. Taking into account that very few studies have attempted to identify variables such as prior knowledge that might confound the effects of questioning on reading comprehension, these results are an important contribution to the preliminary understanding of the role that self generated questions play in reading comprehension.

One of the aspects of questions of interest in this pilot study concerned the types of questions asked. Types or levels of questions posed were found to be an important factor related to knowledge built from text. It was found that students' questions that requested factual information or yes/no types of answers were associated with levels of reading comprehension consisting of factual knowledge and simple associations. As previously described, the structural knowledge organization for these students is characterized by network maps, generated by Pathfinder with some initial clustering of words. These words generally consist of supporting details that are linked to a main concept. However, prominent in these knowledge maps is that word clusters do not denote a hierarchical organization of knowledge in the form of an overarching concept with subordinate concepts connected to it. In fact, these maps depict connected words that indicate simple, factual associations rather than a conceptual organization of knowledge.

On the other hand, students who mostly asked questions that requested conceptual explanations showed ability to organize knowledge from their reading at a conceptual level. As shown in the Pathfinder maps, knowledge that is conceptually organized is characterized by a hierarchical organization in which a main overarching concept is linked to a couple of subordinate concepts which in turn are linked to supporting information (i.e., clusters). The hierarchical organization of knowledge is evident in these maps because clusters of words are clearly distinguishable from each other, while located around the main, super-ordinate concept (for reference see examples of these maps in the Passage Comprehension Scoring section).

Conceptual knowledge built from text that is represented as network maps (in this study by means of Pathfinder) is consistent with current views of reading comprehension. These views support the idea that reading comprehension consists of the organization of text information into a coherent structure (van den Broek & Kremer, 2000). In this view, understanding a text consists of forming a coherent representation of knowledge from text that is similar to a network, with nodes that depict the individual text elements and connections that depict the meaningful relationships between the elements in the text (Trabasso, Secco, van den Broek, 1984; van den Broek & Kremer, 2000).

The present results indicate that there is a relationship between student-generated questions and student reading comprehension. Among the different aspects of questions that have been the focus of inquiry, in this study questions have been examined in terms of types or levels. Specifically, question levels have been defined according to the conceptual complexity of their requests. These levels have facilitated examining the relationship between student questions and reading comprehension. This study adds to the literature first, by suggesting that there is a theoretical important association between *levels* of questions and *levels* of reading comprehension measured as conceptual knowledge built from text. Second, this study adds to the literature by contributing a new measure of students' questions, thereby facilitating research on the potential contribution of this variable to text comprehension.

Chapter IV
Method

Hypotheses

Three research hypotheses are proposed in this dissertation.

1. Students' question levels on the question hierarchy will be positively associated with students' level of text comprehension measured by a Multiple Text Comprehension task and a Passage Comprehension task.
2. Students' questions will account for a significant amount of variance in reading comprehension, measured by a Multiple Text Comprehension task and a Passage Comprehension task, when the contribution of prior knowledge to reading comprehension is accounted for.
3. Students' questions at the lowest levels of the question hierarchy (Level 1) will be associated with reading comprehension levels in the form of factual knowledge and simple associations. Students' questions at higher levels in the question hierarchy (Levels 2, 3 and 4) will be associated with reading comprehension levels consisting of factual and conceptual knowledge.

Design

Data for this study were drawn from a larger investigation of Grade 3 and Grade 4 students (Guthrie, Wigfield, & Barbosa, 2000) that included an assessment administered in September and in December of the school year. Data for this dissertation consisted of assessment data collected in December 2002. Assessment tasks included prior knowledge, questioning, and reading comprehension, all tasks relevant for this study. A random sample of 208 students from the larger study were included in this investigation.

Participants

Two hundred eight students participated in this study. One hundred twenty five 3rd-grade students and 83 4th- grade students from four schools in a small city in a mid-Atlantic state participated with permission of their parents. In the 3rd grade sample, 42% were boys and 58% were girls; 55 % were Caucasian, 27 % were African American, 6% were Asian, 3% were Hispanic, and 9% were identified as Other. In the 4th grade sample, 47% were boys and 53% were girls; 59 % were Caucasian, 28% were African American, 2% were Asian, 6% were Hispanic, and 5% were identified as Other. The proportions of boys and girls are comparable across grades and are relatively close to the proportions of the district as a whole in which 50 % are boys and 50 % are girls. However, the ethnic groups in the sample have a larger proportion of African American students when compared to the proportions in the district as a whole which has a population of 87% Caucasian, 8 % African American, 2% Asian, and 2% Hispanic. On the indicator of poverty, the four schools in the sample have approximately 20% of students qualifying for free and reduced-price meals while district has 13%, showing comparability between the sample and the district population. Both third-and fourth-grade classrooms in all schools are self-contained, with the teacher providing the instruction for approximately twenty-five children.

Materials

Two types of texts on ecology topics were used in this study. A multiple text packet containing topics on two specific biomes was the core text for three of the administered tasks. A shorter text passage describing an animal's survival was the core text for the other three tasks. Both of these texts have been briefly described in a section in chapter II (Attributes of Expository Text) and in more detail in Chapter III in the pilot investigation. I briefly restate the features of these materials.

The multiple text packets focused on two biomes and plant and animal life in them. Texts in this packet simulated a variety of information texts in ecology and were extracted from a variety of second to fifth grade trade books. This packet consisted of three alternative forms: Oceans and Forests (form A), Ponds and Deserts (form B), and Rivers and Grasslands (form C). The three alternative forms were parallel in content difficulty and text structure. Each packet was composed of a total of 22 chapter-like sections, 16 of which were relevant sections to the topic of the packet and six of which were non-relevant sections (i.e., distracters). Biome and animal/plant life information was emphasized equally across sections. The six irrelevant sections (or distracters) included either animals that were improbable to be found in any of the two biomes or topics that bore no relationship to the biomes in the packet. Distribution and organization of sections was the same across all three forms. Besides the 22 sections, each packet had a glossary and an index. The 22 sections were distributed across approximately 75 pages, with a length of three to four pages in each section.

Text difficulty was equally distributed throughout the multiple text packet with eight sections of easy text and eight sections of difficult text. The six non-relevant sections also included an equal number of easy and difficult sections. Text difficulty varied mainly in terms of sentence and paragraph length. Easy text had approximately 3 to 13 words per sentence, an average of two to four sentences per paragraph, and five to six paragraphs per section. Difficult text had approximately 14 to 28 words per sentence, an average of 6 to 10 sentences per paragraph, and 13 to 16 paragraphs per section.

There was an average of two to three illustrations per page, with approximately 100 pictures in black and white and 11 pictures in color. The pictures in these texts generally illustrated a concept in the text (e.g., reproduction) or depicted factual and detailed text information (e.g., number and size of water lilies in a river). The majority of these illustrations had accompanying captions explaining the major features depicted. Most of them were real-life photographs with a smaller proportion of diagrams with numerous captions explaining their components.

The animal passage focused on a description of four ecological concepts in relation to an animal's survival. Text for this passage was extracted from a variety of second-to fifth grade trade books. Four alternative forms were developed: (P) The High Flying Bat, (Q) The Incredible Polar Bear, (R) The Scary Shark, and (S) The Amazing Snake. The four forms were parallel in content and text organization. Text in the passage was organized with an introductory paragraph on the animal and a short list of survival mechanisms. The rest of the text was organized into four sections, each of which described aspects of an ecological concept for the animal. Headings for each of the four ecological concepts preceded each section.

The overall passage was four pages long with two to three paragraphs per page, and about 100 words per page. Sentence length was between 7 to 14 words. There were a total of approximately 10 illustrations per packet (with a minimum of two and a maximum of four illustrations per page). Captions accompanied most of the illustrations. All illustrations were black and white, depicting important features of the animal being described (e.g., shark's three rows of teeth) or capturing an ecological concept (e.g., feeding of the young). Number and distribution of illustrations was the same in all three forms.

Measures

A total of seven tasks were administered to the students over five school days. Six of these measures consisted of: Prior Knowledge for Multiple Text Comprehension; Questioning for Multiple Text Comprehension; Multiple Text Comprehension; Prior Knowledge for Passage Comprehension; Questioning for Passage Comprehension; and Passage Comprehension. The seventh task was the comprehension subtest of the Gates-MacGinitie Reading Test (Form S). Levels 4 and 3 of this test were administered to Grades 4 and 3 respectively. This measure was used to provide a supplementary analysis of the relationships proposed with a standardized measure of reading comprehension. Each of the measures is described in the following subsections.

Prior knowledge for multiple text comprehension. At the beginning of the comprehension assessment, students independently wrote for a maximum of 20 minutes, their prior knowledge on any one of three ecological science topics.

1. Definition: This task consisted of a measure of students' prior knowledge on an assigned topic in ecology. Prior knowledge activation consists of students' recall of what they know about the topic of a text before reading and during reading for the purpose of learning the content as fully as possible, and linking new content to prior understanding. In this task students were prompted to activate their prior knowledge by asking a couple of questions that focused on similarities and differences between two biomes.

2. Procedure: Students were randomly assigned to one of the three alternative forms of the task. The three forms consisted of the same topics covered in the multiple text packets. These topics were: Oceans & Forests (form A) Ponds & Deserts (form B) and Rivers & Grasslands (form C). Students wrote their prior knowledge in provided forms. Directions for this task were printed on the forms and read aloud by the teacher as follows:

> In the space below, write what you know about (e.g., ponds and deserts). When writing your answer, think about the following questions. How are (ponds and deserts) different? What animals and plants live in a (pond)? What animals and plants live in a (grassland)? How do these animals and plants live? How do the plants and animals help each other live? Write what you know. Write in complete sentences. You have 15 minutes to write your answer.

After 7 minutes, the teacher provided the following prompt: "You are doing well. Keep writing if you can. You can turn over the page if you need more room." After 15 minutes, forms were collected. Students' responses to this task consisted of written essays.

3. Example: An essay consisting of prior knowledge on the topic of Ponds & Deserts from a third-grade student follows:

> Deserts are very dry. Ponds are very wet. Deserts and ponds are opposites. At a desert animals don't need a lot of water. They do eat but don't drink as much. There are lots of plants that are in the desert. For example, there are cactuses, and flowers and much, much more. Ponds

have lots of animals. For example, there are ducks, and fish. There are lots of plants like lily pads that frogs jump on and reeds that ducks lay their eggs. Deserts have animals like coyotes, rabbits, snakes, birds, owls and lizards (reptiles). There are many other things about deserts and ponds. Well that's all I have to say about deserts and ponds.

4. Validity and Reliability: Parallel form across-time reliability for the Prior Knowledge for Multiple Text Comprehension Grade 4 was .32 ($p < .01$); Grade 3, .44 ($p < .01$). Parallel form across time reliability was established by correlating students' scores on one of three forms of the Prior Knowledge task in September 2002 with scores on an alternative form of the task in December 2002. Interrater reliability for this task Grade 4 - exact was 70%, and adjacent was 100%; Grade 3 - exact was 80%, and adjacent was 100%. The procedure for establishing interrater reliability was very similar for all three tasks for which interrater reliability is indicated. Two independent raters coded students' responses into the corresponding rubric for the task. Exact agreement was computed to report whether raters concurred on the identical number (coding) for a given response. Adjacent agreement was computed to report whether raters disagreed by one or less on the coding of a response. If exact agreement was below 70%, discrepancies in final scores were resolved by a third independent rater. Concurrent validity for this measure was indicated by the correlation between prior knowledge and multiple-text reading comprehension using the three alternative forms for both of these tasks in December 2002. This

correlation was .45 ($p < .01$) for Grade 3 and it was not statistically significant for Grade 4.

5. Scoring: Students' performance on prior knowledge was rated on the same knowledge hierarchy as the Multiple Text Comprehension task. The hierarchy scores ranged from one to six. A score of 1 (Level 1) corresponds to low prior knowledge and this is evident in essays consisting of briefly stated simple facts. A score of 6 (Level 6) corresponds to high prior knowledge, evident in essays in which students describe complex patterns of relationships among several organisms and their habitats. These types of essays are characterized by concepts and science principles that are thoroughly supported by appropriate examples and statements. The essay example previously presented for this task corresponds to a Level 2 in this hierarchy. Level 2 is characterized by facts and associations often presented in a list. At this level, students can correctly classify several organisms, often in lists, with limited definitions. These classifications are present in the preceding example. The hierarchy used for this scoring scale is described thoroughly in Appendix C. Also, an abbreviated version of this hierarchy is presented in the Scoring section of the Multiple Text Comprehension task.

Questioning for multiple text comprehension. As a first indicator of questioning in relation to text, students asked questions in relation to the multiple text packet.

1. Definition: This task consisted of student questioning about biomes described in a multiple text packet. Questioning refers to students asking or writing self-initiated questions about the content of the text before or during reading to help

them understand the text and topic.

2. Procedure: Students browsed the multiple text reading packets for two minutes. After browsing, students received a questioning form with the following printed directions that were read aloud by the teacher.

> You have been learning about (ponds and deserts). What questions do you have about (ponds and deserts)? These questions should be important and they should help you learn more about (ponds and deserts). You should write as many good questions as you can. You have 20 minutes.

Texts were not available to students during question-generation. Students were provided enough space in the forms to write a maximum of 10 questions. However, students were allowed to write more than 10 questions if they chose to do so.

3. Examples: Grade 3 students' questions about the topic of grasslands and rivers follow:

What kinds of animals live in rivers?

How many rivers are there in the world?

Why do giraffes eat leaves and lions eat meat?

Do any grassland animals go in the rivers?

What kinds of little plants grow in rivers?

Why do salmon swim up river and not down river?

4. Validity and Reliability: Interrater agreement for coding students' questions

to the Questioning Hierarchy for Grade 4 - exact was 84% and adjacent was 98% (43 questions); Grade 3- exact was 90 %, and adjacent was 100% (38 questions). Parallel form across time reliability coefficients were calculated for each of the two indicators for the questioning task, the sum and the mean. Parallel form across time reliability Grade 4 for the sum indicator was .39 ($p < .01$) and .38 ($p < .01$) for the mean indicator. Parallel form coefficients for Grade 3 were .45 ($p < .01$) for the sum indicator and .41 ($p < .01$) for the mean indicator. Internal consistency reliability for this task yielded a Cronbach's alpha coefficient of .83 (10 items). Validity for this task was indicated by the correlation between each of the two indicators of questioning (sum and mean) across the two questioning tasks. The validity coefficient for Questioning for Passage Comprehension *sum* and Questioning for Multiple Text Comprehension *sum* was .27 ($p < .05$) for Grade 4. The validity coefficient for Questioning for Passage Comprehension *mean* and Questioning for Multiple Text Comprehension *mean* was .30 ($p < .01$) for Grade 4. Validity coefficients for these tasks for Grade 3 were: .30 ($p < .01$) for the sum and .26 ($p < .01$) for the mean indicator.

5. Scoring: Students' questions were coded into the four levels of the Questioning Hierarchy presented in Appendix B. Questions for this task were coded into the subcategory corresponding to "Questions about biomes and organisms" in the hierarchy. Two indicators of questioning were used in the analyses, questioning sum and questioning mean. The questioning sum represents the combination of quantity with the quality of students' questions. This indicator is equivalent to the addition of the levels to which a given student's questions are coded. The sum indicator was

calculated by adding the codes assigned to the question levels for each codable question. Questions that could not be coded according to the hierarchy levels were identified and coded 0. Thus, these questions did not contribute to the questioning sum. The questioning mean is the average level of the questions asked. The questioning mean was computed by dividing the sum indicator by the number of questions asked. The number of questions asked included the non-codable questions (coded 0). Therefore, the non-codable questions were included in the computation of the mean indicator. The Questioning Hierarchy is included in Appendix B.

Multiple text comprehension. This task was administered over three sessions in two days. On the first day, students spent approximately 20 minutes on the task. On the second day, students spent a total of approximately 40 minutes searching for information and an additional 30 minutes writing. During the first two sessions, students spent time searching for information, reading and taking notes on their reading. In the third session, students were asked to write about what they learned during their interaction with text in the two previous sessions.

1. Definition: Multiple text comprehension refers to students' competence in identifying text relevant information, reading to obtain question-relevant information, and writing a statement expressing conceptual knowledge gained from performing this task.
2. Procedure: Students were given the multiple text packets described in the *Materials* section. On the first two sessions of this task students interacted with text by searching for information, reading and taking notes. Students took notes for different sections in the packets. Teachers helped students

understand the task by guiding them through an example provided in the directions. Teachers read the following directions aloud:

> Use this packet to learn about (ponds and deserts). Read to answer these questions. How are (ponds and deserts) different? What animals and plants live in a (pond)? What animals and plants live in a (grassland)? How do these animals and plants live? How do the plants and animals help each other live? Later you will be asked to write what you have learned from this packet.
>
> Some of the sections of this packet will be helpful and some will not. Choose the sections that will help you explain how animals and plants live in (ponds and deserts). Write the letter of the section you choose to read. Read the sections for as long as you want in order to answer the questions. Write down what you have learned on the lines provided.
>
> Now, let's try an example together. Look at the table of contents in your packet. Suppose we wanted to learn more about (oceans). One section we may want to look in would be named "Oceans." This section in the table of contents is labeled section M. Everyone find section M in the table of contents. Point to it. Now look at your search notes. Everyone point to the line where you think you should write the section letter M. When you have found the line write the letter M on that line"

The teacher made sure the students wrote an M on the line and that they followed the example. The teacher continued:

Now look back at the table of contents. Point to the page number where Section M begins. That page is __. Turn to that page and begin reading the whole section. Section M is four pages long. As you read this section write what you learned by “*what I learned.*” You do not have to worry about spelling and punctuation. You have 5 minutes to read and write as much as you can. Then STOP and wait for more directions.

Students were provided with 10 spaces to write about 10 sections. After students completed the example along with their teacher, the teacher continued reading directions: “Now you will use this packet to learn about (oceans and forests). Read to answer these questions”. (The teacher will read the same prompts given for the prior knowledge task). Directions continued: “Now you choose the sections for the reading packet you want to read. Do this just like you did the last one. Stop after you have finished page 2 of your notes. You will have 10 minutes to do this”. Due to its extensiveness, students were able to complete this part of the task in two days. On the first day, students were required to complete the example and 2 of the 10 sections. During the second session, students were told to continue where they had left off and continue with their search. Students stopped their writing when they finished completing all 10 sections or after 40 minutes. Students had the choice to select any sections they wanted to take notes on.

During the third session of the task, students were encouraged to review their notes for five minutes. After this, students’ notes and text packets were collected and the teacher read the directions for students' writing. Directions were:

> In the space below, write what you know about living in (oceans and forests). Think about the following questions. How are (oceans and forests) different? What animals and plants live in a (forest)? What animals and plants live in a (ocean)? How do these animals and plants live? How do the plants and animals help each other live? Write everything you know. Write in complete sentences. You have 25 minutes.

The teacher prompted students twice, after 7 minutes and after 20 minutes by saying, "You are doing well. Keep writing. You can turn over your page if you need more room." Students' essays were collected after 30 minutes.

3. Example: A third-grade student's Level 6 essay corresponding to the writing section of this task follows:

    > Grassland and rivers are different because grasslands are dry and have few water and rivers are a channel with water in it. Water lilys *(sic)*, trouts, salmon, sea wasp, lotuses, water weed, otters, piranhas, and platypus all live in a river. Elephants, cheetahs, deers *(sic)*, birds, rinos *(sic)*, grass, flowers, trees, butterflies, hyenas, and puff adder all live in grassland. Animals drink, eat, and sleep to live, plants also drink, eat, sleep, and also need sunlight. Plants help animals by making oxygen and when animals die they can fetalize *(sic)* the soil and that is good for plants.

4. Validity and Reliability: Interrater agreement into the categories of the conceptual knowledge hierarchy for Grade 4 - exact was 70%, and adjacent was 100%; Grade 3 - exact was 60%, and adjacent was 95%. A second round

of agreements was established by the same two raters for Grade 3. Because similar percentages for adjacent and exact agreements were reached in both rounds, discrepancies in final scores were resolved by a third independent rater. Parallel form across time reliability was indicated by using all three alternative forms for this task taken in September and December 2002. Parallel form reliability for Grade 4 was .28 ($p < .05$); Grade 3 was .38 ($p < .01$). Concurrent validity coefficients were indicated by the correlation of the Multiple Text Comprehension task with the Gates-MacGinitie reading test, a standardized reading measure administered to these students. These validity coefficients were .48 ($p < .01$) for Grade 4 and .31 ($p < .01$) for Grade 3.

5. Scoring: Scores for this task consisted of students' essay scores on the hierarchy for conceptual knowledge. The same knowledge hierarchy was used to score students' responses to the Prior Knowledge for Multiple Text Comprehension task. A complete version of this hierarchy is included in Appendix C. A shortened description of each of the levels in the Knowledge Hierarchy for Ecological Science is presented here.

(a) Facts and associations (simple) Level 1: Students present a few characteristics of a biome or an organism; (b) Facts and associations (extended) Level 2: Students correctly classify several organisms, often in lists, with limited definitions. (c) Concepts and evidence (simple) Level 3: Students present well-formed definitions of biomes with many organisms correctly classified accompanied by one or two simple concepts with minimal supporting evidence. (d) Concepts and evidence (extended). Level 4: Students display several concepts of survival illustrated by specific organisms with their physical characteristics and behavioral patterns. (e) Patterns of relationships (simple). Level 5: Students convey knowledge of relationships among concepts of survival supported by descriptions of multiple organisms and their habitats. (f) Patterns of relationships (extended) Level 6: Students show complex relationships among concepts of survival emphasizing interdependence among organisms.

Prior knowledge for passage comprehension. The three tasks described next refer to the animal text passage. Prior Knowledge for Passage Comprehension was a new measure used with the sample for this dissertation and was not used in the pilot study reported in this dissertation. For this second indicator of prior knowledge, students completed a multiple-choice task of prior knowledge on one of four animals.

1. Definition: In this task, prior knowledge activation consists of students' selection of words or phrases that reflect their knowledge about the topic before reading. The purpose is to link new content to prior understanding. This task consisted of students' judgments of similarity of words in a multiple-choice format. For each item, students had to identify one of four alternatives that made the most sense with the word-stem.
2. Procedure: Four alternative forms were used for this task. Each of these forms consisted of one of the four animals that the reading passages were about (i.e., bat, polar bear, shark, snake). The task was in multiple-choice form, with an example item and a total of 22 items. Each item consisted of a word or a short phrase stem and four answer choices. Items varied in difficulty level with more difficult items located towards the end of the form. All items captured essential

characteristics of the corresponding animal. The task was administered to the students by the classroom teacher according to the following directions:

> For each item, choose one word that is most like the given word about (bats). In the example, the given word is (bat). Is the word most like the word “a” animal, “b” tree, “c” soccer, or “d” sky? Circle the letter of the word that is most like the word (bat)? What is the answer? (Teacher waited for a response). Yes, the answer is “a” animal.

The teacher read the rest of the items in the same manner, stating the word (stem) and each answer choice aloud.

4. Example: Two items with different difficulty levels for the topic of bats are presented here:

Item #1. Bats	Item #10. Echolocation
a) Reptiles	a) Hanging
b) Birds	b) Seeing
c) Mammals	c) Stretching
d) Insects	d) Finding

5. Reliability: Grade 4 parallel form across time reliability was .31 ($p < .01$) and Grade 3 was .33 ($p < .01$). Internal consistency, Cronbach alpha coefficients for each of the alternative four forms were as follows: Bat .42; Polar Bear .58; Shark .53; and Snake .71. Predictive validity for Prior Knowledge for Passage Comprehension was indicated by its correlation with Passage Comprehension. Grade 4 predictive validity was .41 ($p < .01$); Grade 3 was .34 ($p < .01$).

6. Scoring: Scores for this task were based on right or wrong answers for each item.

Questioning for passage comprehension. As a second indicator of questioning students asked questions about the animal passage.

1. Definition: This task consisted of student questioning about a specific animal described in a reading passage. Questioning refers to students asking or writing self-initiated questions about the content of the text before or during reading to help them understand the text and topic.
2. Procedure: Students browsed the reading passages for two minutes. After browsing the passages, students received a questioning form with printed directions. Directions were read aloud by a trained graduate student as follows: "Write as many good questions about the (shark) as you can." Texts were not available to students while they wrote their questions. They were provided 10 spaces for question writing. Forms were collected after 15 minutes.
3. Example: A Grade 3 student's questions about polar bears follow:

   How do polar bears make their dens?

   How do polar bears catch fish?

   Why are polar bears white?

   What are the dangers for the polar bears?
4. Validity and Reliability: Interrater agreement for this task for Grade 4 – exact was 87% and adjacent was 98% (46 questions); Grade 3- exact was 90 %, and adjacent was 100% (20 questions). As previously suggested, internal consistency reliability for this task increased with a higher number of items. Cronbach alpha for this task was .83. Validity for this task for Grade 4 was

indicated by the correlation between each of the two indicators of questioning (sum and mean) across the two questioning tasks. The validity coefficient for Questioning for Passage Comprehension *sum* and Questioning for Multiple Text Comprehension *sum* was .27 ($p < .05$) for Grade 4. The validity coefficient for Questioning for Passage Comprehension *mean* and Questioning for Multiple Text Comprehension *mean* was .30 ($p < .01$) for Grade 4. Validity coefficients for these tasks for Grade 3 were .30 ($p < .01$) for the sum and .26 ($p < .01$) for the mean indicator.

5. Scoring: Students' questions were coded into the four levels of the Questioning Hierarchy included in Appendix B. Questions for this task were coded to the subcategory corresponding to "Questions about animals" in the hierarchy. The two indicators of questioning, sum and mean, used in the Questioning for Multiple Text Comprehension task were computed for this task and used in the analyses.

Passage Comprehension. As a second indicator of text comprehension students were given the task of rating the relatedness of text words. Students spent approximately 25 minutes on this task. This task assessed comprehension by assessing the conceptual knowledge structure that students generate based on similarity ratings of word pairs. Four alternative forms were utilized for this task. These forms corresponded to the four forms of the animal passage. In addition, two levels were used to better capture the difference of performance on this task between grades 3 and 4. These two levels- Levels 3 and 4- differed in the number of items and the number of word pairs to be rated. In Level 3, students rated the relatedness of nine words for 36 word-pairs; in Level 4, students rated the relatedness of 13 words for 78 word-pairs. As a consequence of a higher number of words and comparisons, Level 4 included one more concept with supporting facts in its expert model (i.e., three ecological concepts in Level 4 compared to two concepts in Level 3).

1. Definition: This task consisted of students' ratings of the relatedness of key words extracted from the reading passage.
2. Procedure: Directions were read by the same trained graduate student who administered the Questioning for Passage Comprehension task. Directions were:

   > Everybody hold up your reading passage. It should look like this. Let's read the title together. "Read the title". Yes the title is "Read the title". Now, read the passage. Look for big ideas, important relationships, and important facts. Please remember these big ideas, important relationships and important facts. You have 10 minutes.

   After reading the text, students were directed to a proximity-ratings example sheet. On this sheet three examples were provided. For each example a pair of words to be related on a scale from 1 to 9 was presented. Students were guided through each of these examples with an explanation of the similarity or lack of thereof between each pair of words. The ratings values (numbers 1, 5 and 9) for each pair were also explained in detail. A rating value of 9 was equivalent to words being "very related", a value of 5 to words being a "a little bit related" and a value of 1 to words being "not related at all". To ensure that the students were following and were able to read and identify the example words, the test administrator said, “Everyone put their finger on *wolf* and *fangs* in the middle of the page like this” (showing the students the words on the page). “Are wolf and fangs related?” (The administrator waited for student responses). The administrator continued, “Yes, a wolf has fangs. You would give those words that are related a 9. Circle the 9 on your paper.” The same directions were given for the other two examples, which had ratings of 1 and 5. To facilitate students’ understanding, the graphics on the rating sheet were the same as the graphics on the computer screen. Directions proceeded as follows:

> Now you will show what you have learned from the packet. We will use the computer to do this. Press the space bar one time. What words do you see at the top of the screen? These words are from your (animal) passage. Please point to the words as I read them. The first word is___. Point to this word. (The administrator did this for every word to guarantee that all words were decodable for all students).
>
> Hit the space bar. Look at the two words in the middle. You do not have the same words as your neighbor. This is OK. Look at your words and decide how related they are. Press a 9 if they are very related, press a 1 if they are not at all related, and press a 5 if they are a little bit related. You can change your answer by pressing a different number if you wish.
>
> Once you are sure of your number press the space bar. New words will appear. Decide how these words are related. Then press the space bar. Do the rest of the words until you get to the end.

After 15 minutes, students were instructed to raise their hands when the screen read "STOP."

Nine words were selected from each alternative form for Level 3 and 13 words were selected for Level 4. This yielded 36 word pairs for Level 3 and 78 word pairs for Level 4. As described earlier, word selection was done by experts in the field of ecology and was based on the saliency they were assumed to have for a conceptual knowledge representation of the text.

3. Example: Pathfinder, the computer program used to assess passage reading comprehension, generates graphic representations (network maps) based on the relatedness ratings. A network map displays the connection among node-words based on students' ratings. Networks vary as a function of the correlation score the system generates. Network maps corresponding to different score levels were presented in the pilot study section in this dissertation.
4. Validity and Reliability: Internal consistency reliability estimates were indicated for each of the four alternative forms used for each level (Levels 3 and 4). Cronbach alpha coefficients were as follows: The High Flying Bat, Level 4, .94; Level 3, .85; The Incredible Polar Bear, Level 4, .89; Level 3: .88; The Scary Shark, Level 4, .93; Level 3, .83; The Amazing Snake, Level 4, .94; Level 3, .86. Concurrent validity for this task was indicated for this sample by examining the correlations between the Passage Comprehension task and two other measures of reading comprehension. One of these measures, the Multiple Text Comprehension task, is a more traditional measure of reading comprehension than the Passage Comprehension task, thus suggesting an

adequate indicator of validity for this task. This correlation was .38 ($p < .01$) for Grade 4 and .31 ($p < .01$) for Grade 3. Scores on the Gates-MacGintie Reading Tests, (Fourth Edition, 2002), a standardized measure of reading comprehension, were correlated as well with scores on the Passage Comprehension task. These correlations were .50 ($p < .01$) for Grade 4 and .44 ($p < .01$) for Grade 3. Significance of the correlations suggested adequate concurrent validity for the Passage Comprehension task.

5. Scoring: This task assessed the conceptual knowledge structure that students generated based on the ratings of relatedness of word pairs. Students rated the similarity of words based on a three-point scale of 1 (non-related), 5 (somewhat/ a little bit related) and 9 (very related). For Level 3, students rated the relatedness of nine words (36 word-pairs) and for Level 4, students rated the relatedness of 13 words (78 word-pairs). Words for each alternative form follow: The High Flying Bat, Level 3: *Survival, eat, protect, blood, insect, lick, hide, escape, shelter*; Level 4: *Survival, eat, protect, blood, insect, lick, hide, escape, shelter, birth, pups, sniff, carry.* The Incredible Polar Bear, Level 3: *Survival, move, protect, steer, webbed, swim, fur, fat, den*; Level 4: *Survival, move, protect, steer, webbed, swim, fur, fat, den, hunt, prey, capture, seal*. The Scary Shark, Level 3: *Survival, hunt, birth, smell, stuns, teeth, purse, cord, hatched*; Level 4: *Survival, hunt, birth, smell, stuns, teeth, purse, cord, hatched, move; swerve, jump, waves.* The Amazing Snake, Level 3: *Survival, hunt, move, fangs, squeeze, poison, climb, wavy, scales*; Level 4: *Survival, hunt, move, fangs, squeeze, poison, climb, wavy, scales, protect, color, hide, pretend.*

Note that Level 4 differs from Level 3 by having four extra words. These four extra words constitute an extra ecological concept with three supporting facts within the expert Pathfinder knowledge structure as compared to the Level 3 expert model. Pathfinder computes a correlation (Pearson r) between a student's pair-wise ratings and an expert's ratings equivalent to a model score of relatedness ratings (Johnson, Goldsmith & Teague, 1994). These correlation coefficients represent a measure of concordance between each student and a referent representation (Johnson, Goldsmith & Teague, 1994). Correlation scores range from –1 to +1. Pathfinder also generates graphic network representations (i.e., network maps) based on the relatedness ratings. A network map displays the connection among nodes based on the students' ratings. Network maps can be associated with their corresponding correlation scores, providing a representation of the knowledge structure of the rater by a visual means.

Gates-MacGinitie Reading Tests. The comprehension tests of Levels 3 and 4 (Form S) of this standardized measure of reading comprehension were used in this study. These tests consist of approximately 12 paragraphs on varied subjects with a range of 2 to 6 questions on each paragraph for students to answer. The extended scale score was used for all statistical analyses.

Administrative Procedures

All seven tasks were administered over five days in the first and second weeks of December, 2002. All Multiple Text Comprehension measures (i.e., Prior Knowledge for

Multiple Text Comprehension, Questioning for Multiple Text Comprehension, and Multiple Text Comprehension) and the Prior Knowledge for Passage Comprehension measure were administered by the classroom teacher. However, Questioning for Passage Comprehension and Passage Comprehension were administered by a trained graduate student in the computer lab of each school. An aide was available at each computer lab to assist the administrator. Teachers were present during the administration in the computer lab and were asked to intervene only if behavioral problems arose. Students were told that they would take some tests and that these would help teachers and some researchers learn about their reading.

As described, administration time varied from 20 to 40 minutes each day. Administration sequence throughout the five days was as follows:

- Day 1: Prior Knowledge for Multiple Text Comprehension, Multiple Text Comprehension (Session 1)* and Questioning for Multiple Text Comprehension.
- Day 2: Multiple Text Comprehension (Sessions 2 and 3)
- Day 3: Prior Knowledge for Passage Comprehension
- Day 4: Questioning for Passage Comprehension and Passage Comprehension
- Day 5: Gates-MacGinitie

Teachers became familiar with the administration sequence and directions for all assessment tasks were provided to them one week in advance of the assessment week. In addition, teachers were told that they would be able to answer students' questions about

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* As described, the Multiple Text Comprehension task was divided into three sessions over three days. The first two sessions consisted of interaction with text by searching, reading and writing. The third session consisted of a written response to text.

directions, but that they should refrain from answering questions on text or assessment content. When task administration lasted more than 25 minutes per day students had a short break. However, if administration for the day took less than 25 minutes, students were encouraged to keep working until they had finished to avoid unnecessary distractions.

Chapter V
Results

The first hypothesis was that students' question levels on the question hierarchy would be positively associated with students' level of text comprehension measured by a Multiple Text Comprehension task and a Passage Comprehension task. The correlations among these variables for both grades are presented in Table 11. The means and the standard deviations for each variable are presented in Table 12. For both grades, this hypothesis was addressed by examining the correlations of the cognitive variables of reading comprehension for multiple texts, questioning for multiple texts and prior knowledge for multiple texts on one hand, and the correlations of passage reading comprehension, questioning for passage comprehension and prior knowledge for passage comprehension on the other. For Grade 4, of the two questioning indicators, the mean indicator of questioning for multiple text comprehension correlated significantly with multiple text reading comprehension at .52 ($p < .01$) and the sum indicator for questioning for multiple text comprehension was not significant (see Table 11). However, for questioning for passage comprehension the sum, rather than the mean indicator, correlated significantly with passage reading comprehension at .41 ($p < .05$), but questioning (mean) for passage comprehension was not significant.

For Grade 3, the sum and the mean indicators of questioning for multiple texts correlated with multiple text reading comprehension at .43 ($p < .01$) and .38 ($p < .01$) respectively. Additionally, each of the questioning indicators for multiple text comprehension correlated significantly with prior knowledge for multiple text comprehension. Questioning (sum) for multiple text comprehension correlated with prior knowledge for multiple text comprehension at .41 ($p < .01$) and questioning (mean) correlated with prior knowledge for multiple texts at .31 ($p < .01$). No significant correlations were found between either questioning indicator for passage comprehension and passage reading comprehension for third graders.

The positive association between questioning and reading comprehension was further supported by the correlations between questioning for multiple texts and the Gates-MacGinitie test, a standardized measure of reading comprehension. This test provided a supplementary analysis for the relationships proposed. As shown in Table 11, for Grade 4 students, the Gates-MacGinitie and questioning for multiple text comprehension correlated .59 ($p < .01$) (sum) and .67 ($p < .01$) (mean). For Grade 3, the Gates-MacGinitie correlated with questioning for multiple text comprehension at .30 ($p < .01$) (sum) and .34 ($p < .01$) (mean).

The second hypothesis stated that students' questions would account for a significant amount of variance in reading comprehension, measured by a Multiple Text Comprehension task and a Passage Comprehension task when the contribution of prior knowledge to reading comprehension was accounted for. To examine this hypothesis eight regression analyses were conducted. Following Cohen (1977), if for these analyses the alpha value was set at .05, power was set at .80 and a medium effect size of .15 was desired (all conventional values), the necessary sample size to meet these specifications would be 55. Seven of the analyses had sample sizes larger than 55, therefore sample size requirements were satisfied. One analysis had a sample size lower than this requirement (i.e., regression of Questioning Sum on Passage Comprehension for Grade 4 students).

However, because this regression produced a result significant at .05 it was assumed that the test had satisfactory power.

Dependent variables for the regression analyses consisted of one of the three reading comprehension measures, namely multiple text comprehension, passage comprehension and the Gates-MacGinitie comprehension test. The independent variables consisted of the cognitive variables of prior knowledge, questioning for multiple texts and questioning for passage comprehension. In all analyses prior knowledge was entered first and questioning was entered second. This order of entry had the purpose of determining the contribution of the independent variable of interest, in this case, student questioning, when the other potential contributing variable to reading comprehension, prior knowledge, was entered first. Missing data were handled with pair wise deletion. Results are presented for Grade 4 first and Grade 3 second.

Grade 4 results are shown in Table 13. Four regression analyses showed that questioning accounted for a significant amount of variance over and above that accounted for by prior knowledge in reading comprehension. Questioning (mean) accounted for a significant proportion of variance in multiple text reading comprehension when prior knowledge for multiple text comprehension was accounted for. This is shown in Table 13 by the significance of the increment of variance associated with questioning (mean) for multiple text comprehension. After prior knowledge was accounted for, questioning (mean) accounted for 9.9% of the variance in multiple text comprehension, which was significant ($F\Delta = 7.436$, $df = 1, 66$, $p < .008$). The multiple R was .34, and the final beta for questioning (mean) was .315 ($p < .008$). The proportion of variance accounted for by prior knowledge in multiple text comprehension was not statistically significant.

When prior knowledge and questioning for multiple-text reading comprehension were divided into high and low categories, the high questioning/high prior knowledge group performed higher in reading comprehension (*M* = 3.25) than the low questioning/high prior knowledge group (*M* = 3.10) (see Table 15). These descriptive statistics contribute to the description of the association between questioning and reading comprehension. In the multiple-regression analysis the questioning sum indicator did not account for a significant proportion of variance in multiple text comprehension for fourth graders.

With passage comprehension as the dependent variable, questioning, with the sum indicator, accounted for a significant amount of variance in passage reading comprehension over and above that accounted for by prior knowledge for passage comprehension (see Table 13). After prior knowledge was accounted for, questioning (sum) for passage comprehension accounted for 10.5% of the variance in passage comprehension, which was significant ($F\Delta = 4.261$, $df = 1, 32$, $p < .047$). The multiple *R* was .46, and the final beta for questioning (sum) was .341 ($p < .047$). Again, descriptive statistics showed that the high questioning/high prior knowledge group was higher in passage reading comprehension (*M* = .54) than the low questioning/high prior knowledge group (*M* = .52) (see Table 15).

Of the two levels of the Passage Comprehension task, Level 4 (the longer animal passage text, with 78 word-pairs) was the one utilized in this analysis as this was the passage level for which questioning added significantly to the prediction of passage reading comprehension. Neither prior knowledge nor questioning (either indicator) added significantly to the prediction of reading comprehension when Level 3 of the Passage

Comprehension task (the shorter form, with 36 word-pairs) was the outcome variable in the regression analysis.

The two last analyses reported in Table 13 indicate that in the first of these regressions the sum for questioning and, in the second regression, the mean for questioning for multiple text comprehension contributed significant proportions of the variance in the Gates-MacGinitie test over and above the variance accounted for by prior knowledge for multiple text comprehension. After prior knowledge was accounted for, questioning (sum) for multiple text comprehension accounted for 12% of the variance in the Gates-MacGinitie reading comprehension test, which was significant ($F\Delta = 9.316$, $df = 1, 64$, $p < .003$). The multiple R was .41, and the final beta for questioning (sum) was .354 ($p < .003$).). After prior knowledge was accounted for, the mean indicator of questioning explained 18.3% of the variance in the Gates-MacGinitie test, which was significant ($F\Delta = 15.353$, $df = 1, 64$, $p < .001$). The multiple R was .48 and the final beta for questioning (mean) was .429 ($p < .001$). However, analyses at the descriptive level showed that with either questioning indicator, the high questioning/high prior knowledge group did not have higher average scores on the Gates Mac-Ginitie test ($M = 484.89$, sum indicator; $M = 484.38$, mean indicator) when compared with the low questioning/high prior knowledge group ($M = 488.22$, sum indicator;$M = 488.30$, mean indicator) (see Table 15).

These results show that Grade 4 student questioning predicted reading comprehension across three reading comprehension tasks even after accounting for prior knowledge of the topic domain for two of the comprehension tasks. Questioning within the domain of ecological science (measured by questioning for multiple text comprehension) also predicted reading comprehension in an unrelated domain such as the topics covered by the Gates-MacGinitie's reading test. In other words, when controlling for the contributions of prior knowledge to reading comprehension, questioning added significantly to the predictability of reading comprehension across different topic domains for Grade 4 students.

For Grade 3, regression analyses with the dependent variables of multiple text comprehension, Gates-MacGinitie, and passage comprehension were conducted. However, Table 14 shows results only for the regressions of questioning and prior knowledge on the dependent variables of multiple text comprehension and the Gates-MacGinitie test, since questioning did not add significantly to the predictability of passage reading comprehension for Grade 3 students. The results shown in Table 14 indicate that questioning accounted for a significant amount of variance over and above that accounted for by prior knowledge in multiple text reading comprehension when using either questioning indicator. After prior knowledge was accounted for, questioning (mean) for multiple text comprehension accounted for 6.7% of the variance in multiple text reading comprehension, which was significant ($F\Delta = 10.275$, $df = 1, 113$, $p < .002$). The multiple R was .52, and the final beta for questioning (mean) was .271 ($p < .002$). With the sum indicator, questioning accounted for 7.5% of the variance ($F\Delta = 11.628$, $df = 1, 113$, $p < .001$) to the prediction of multiple text comprehension after prior knowledge was accounted for. The multiple R was .52, and the final beta for questioning (sum) was .300, which was significant ($p < .001$). As shown in Table 15, the high questioning/high prior knowledge group was higher on multiple-text reading comprehension ($M = 3.50$) than the low questioning/high prior knowledge group ($M = 2.50$) when using the questioning mean indicator in the analyses. Similarly, with the sum indicator the high questioning/high prior knowledge group was higher on multiple text reading comprehension (*M* = 3.33) than the low questioning/high prior knowledge group (*M* = 2.67).

With the Gates-MacGinitie reading comprehension test as the dependent variable, questioning for multiple text comprehension accounted for a significant proportion of variance over and above that accounted for prior knowledge for multiple text comprehension only when the mean indicator was used. After prior knowledge for multiple text comprehension was accounted for, questioning (mean) for multiple text comprehension accounted for 5% of the variance in the Gates-MacGinitie comprehension test, which was significant ($F\Delta = 7.778$, $df = 1, 120$, $p < .006$). The multiple *R* was .47, and the final beta for questioning (mean) was .236, which, was significant ($p < .006$). Scores on the Gates-MacGinitie test for the high questioning/high prior knowledge group (*M* = 502.44) were higher than scores for low questioning/high prior knowledge group (*M* = 482.63) (see Table 15). However, when the sum indicator was used in the multiple regression analysis, questioning did not account for any significant amount of variance in the Gates-MacGinitie comprehension test above that accounted for prior knowledge.

Results for Grade 3 students show that student questioning predicted reading comprehension for two of the three reading comprehension reading tasks, namely Multiple Text Reading Comprehension and the Gates-MacGinitie standardized test, above and beyond the predictability of prior knowledge in the domain of ecological science. These results show that when controlling for the significant contributions of prior knowledge to reading comprehension, questioning was a strong predictor of reading comprehension across two different tasks as evidenced by the substantial final betas.

The third hypothesis was that students' questions at the lowest levels of the question hierarchy (Level 1) would be associated with reading comprehension levels in the form of factual knowledge and simple associations, whereas, students' questions at higher levels in the question hierarchy (Levels 2, 3 and 4) would be associated with reading comprehension levels consisting of factual and conceptual knowledge.

A chi-square test for independence was used to address this hypothesis. The chi-square test for independence is used to determine whether or not there is a relationship between two variables when the data consist of frequencies. Because this hypothesis stipulated an association between frequencies of question levels and frequencies of levels of conceptual knowledge, the chi-square test for independence was the statistical procedure selected to test the association between these variables.

Frequencies of scores were computed for the variables of questioning for multiple text comprehension (mean indicator) and multiple text reading comprehension. The mean indicator of questioning was used for both grades due to its predictive value in reading comprehension for multiple texts. The score distributions for each of the variables were categorized as low and high. Low questions consisted of question levels that reflected factual knowledge (defined as Level 1 in the Question Hierarchy). High questions consisted of question levels that reflected conceptual and factual knowledge (defined as Levels 2, 3 and 4 in the Question Hierarchy). The categorization of low and high questions was based on cut off values determined for each distribution of scores (i.e., distribution of scores for grades three and four respectively). Cut off values for the distribution of question levels were obtained by computing the median for the distribution of the questioning mean indicator for each grade. Each distribution was divided into two categories: scores equal or below the median corresponded to low level questions and scores above the median corresponded to high level questions. The medians for the score distributions of the questioning mean indicator were 1.60 and 1.33 for Grades 4 and 3 respectively.

Scores for the multiple-text comprehension task were also categorized into high and low levels of conceptual knowledge according to where they fell in relation to the median of each distribution of scores. The distribution of scores for multiple text comprehension for each grade was divided into scores falling either, equal or below the median (low scores) or scores falling above the median (high scores). The medians for the score distributions of the Multiple Text Comprehension task were 3.00 for Grade 4 and 2.00 for Grade 3.

The Chi-square statistic tests the "independence" or lack of relationship between the two variables that are hypothesized to be related. In this case, the chi-square tested whether question levels were independent of the levels of conceptual knowledge. Statistically, observed, sample frequencies (f_o) are compared to expected frequencies (f_e) defined by a hypothetical distribution that is in agreement with the null hypothesis of no relation between the two variables. The Chi-square test for independence (Pearson Chi-square) measures the discrepancy between the observed frequencies and the expected frequencies. Therefore, a large discrepancy would produce a large, significant value for Pearson Chi-square and would indicate that the hypothesis of no relationship between the two variables should be rejected. Table 16 (Grade 4) and Table 17 (Grade 3) show the observed frequencies in the form of a 2X2 matrix, where the rows correspond to the two categories of the multiple text comprehension variable, and the columns correspond to the two categories of the questioning variable. For Grade 4, the Pearson Chi-square statistic was 6.414 with an associated probability value of less than .011 ($X^2 = 6.414$, $df = 1$, $N = 74$, $p < .011$). This indicates that the hypothesis of independence between the two variables can be rejected. This probability value should suffice to reject the null hypothesis of no relationship between the two variables. However, the Chi-square test requires that in order to avoid probability values of Chi-square statistics being distorted, 2X2 tables should not have cells with an expected value of less than five. This assumption was met in this analysis since no cells had expected counts of less than five. Therefore, these results support an association between questioning levels and levels of conceptual knowledge built from text measured by the Multiple Text Comprehension task for Grade 4 students. Note that the majority of the students (63%) were located in the low questioning/low multiple text comprehension group (Table 16) and in the high questioning/high multiple text comprehension group (represented by the diagonal in Table 16). The higher proportion represented by these two groups gave the significant association between these variables. A minor exception to the association was that the group with high questioning/high multiple text comprehension had a lower frequency (14) than the group with high questioning/low multiple text comprehension (22).

Results for Grade 3 students consisted of a Pearson Chi-square of 11.431, which was significant ($X^2 = 11.431$, $df = 1$, $N = 125$, $p < .001$). No cells had expected counts of less than five. As it was the case for Grade 4, these results support the hypothesis that there is an association between levels of questions and levels of conceptual knowledge as measured by the Multiple Text Comprehension task for Grade 3 students.

To examine how third graders compared to fourth graders in questioning I conducted a univariate ANOVA. The means for questioning for multiple text comprehension for each grade (shown in Table 12) were compared by using an F test. The results showed that fourth graders (M =1.65) were higher than third graders (M =1.30), which was significant (F = 13.341, df = 1, 207, p < .001).

Differences between Grade 4 and Grade 3 students are also shown in Table 18. This table shows percentages of questions asked according to the mean indicator of the Questioning for Multiple Text Comprehension task. Percentages of questions for each level range evince that there were differences in the patterns of the questions asked by each grade. For the low level range (.0-.9), Grade 4 students asked less than half as many questions (10%) as Grade 3 students (24 %). Questions in this level range were non-meaningful, or “non-codable” according to the Questioning Hierarchy levels.

For the medium level range (1.0-1.9) Grade 4 students (70%) and Grade 3 students (67%) asked a similar proportion of questions. For the high level range (2.0-2.9), Grade 4 students asked twice as many questions (18%) than third graders (9%). In other words, Grade 4 students asked, on average, twice as many above-Level 2 questions as Grade 3 students. For the highest level range (3.0-4.0) Grade 4 students asked a small proportion (2%) of these questions compared to no questions asked at this level for the younger third graders.

The two prior knowledge measures used in this dissertation were compared in terms of their associations with questioning and reading comprehension. Table 19 shows this specific set of correlations, which are also included in the correlation matrix in Table 11. An overview of these correlations shows that both Prior Knowledge for Multiple-Text Comprehension and Prior Knowledge for Passage Comprehension correlated more often with the questioning and reading comprehension measures for Grade 3 than for Grade 4. When comparing the multiple-choice prior knowledge measure (Prior Knowledge for Passage Comprehension) with the more open, less prompted measure of prior knowledge (Prior Knowledge for Multiple Text Comprehension), the former correlated with Passage Comprehension and the Gates-MacGinitie test but did not correlate with the Questioning task for Passage Comprehension. This pattern appears for both grades. The Prior Knowledge for Multiple Text Comprehension task, on the other hand, correlated with all three measures of reading comprehension and the Questioning for Multiple Text Comprehension task for third graders. None of these correlations were observed for Grade 4 students.

le 11

rrelations Among Questioning, Prior Knowledge and Reading Comprehension for Grades 3 and 4

gnitive Variables	1	2	3	4	5	6	7	8	9
Questioning Sum MTC	___	.65**	.30**	.11	.41**	.43**	.26**	.16	.30**
Questioning Mean MTC	.61**	___	.07	.25**	.31**	.38**	.34**	.28**	.34**
Questioning Sum PC	.08	.01	___	.55**	.16	.23*	.13	.05	.01
Questioning Mean PC	.05	.15	.27	___	.01	.13	.16	.12	.09
Prior Knowledge MTC	.10	.15	.23	- .20	___	.45**	.45**	.38**	.41**
MTC	.31	.52**	.23	.49**	.19	___	.30**	.31**	.31**
Prior Knowledge PC	.27	.40*	.31	.06	.29	.30	___	.33**	.36**
PC	.45*	39*	.41*	.12	.34	.42*	.33**	___	.44**
Gates-MacGinitie	.59**	.67**	.33	.28	.23	.53**	.40**	.45**	___

e. Correlations for Grade 3 are above the diagonal; those for Grade 4 are below the diagonal. MTC = Multiple Text mprehension; PC = Passage Comprehension.
$< .05$; $^{**}p < .01$.

Table 12

Means and Standard Deviations for all Variables for Grades 3 and 4

Cognitive Variables	Grade 3	Grade 4
Questioning Sum MTC		
M	9.87	11.66
SD	4.78	6.00
Questioning Mean MTC		
M	1.30	1.65
SD	.52	.62
Questioning Sum PC		
M	13.35	14.54
SD	4.66	5.91
Questioning Mean PC		
M	1.63	1.86
SD	.43	.52
Prior Knowledge MTC		
M	1.97	2.17
SD	.69	.55
Multiple Text Comprehension		
M	2.46	2.93
SD	.98	1.03
Prior Knowledge PC		
M	7.93	8.06
SD	2.27	2.05
Passage Comprehension		
M	.386	.437
SD	.198	.242
Gates- MacGinitie		
M	471.72	476.61
SD	35.32	38.88

Note. MTC = Multiple Text Comprehension; PC = Passage Comprehension.

le 13

ression Analyses of Prior Knowledge and Questioning on Three Text Comprehension Variables for Grade 4 Students

endent and Independent riables	*R*	R^2	ΔR^2	$F\Delta$	*Final* β
ltiple Text Comprehension					
Prior Knowledge MTC	.136	.018	.018	*ns*	*ns*
Questioning Mean MTC	.343	.118	.099	7.436**	.315**
sage Comprehension					
Prior Knowledge PC	.326	.106	.106	*ns*	*ns*
Questioning Sum PC	.460	.211	.105	4.261*	.341*
es-MacGinitie					
Prior Knowledge MTC	.225	.051	.051	*ns*	*ns*
Questioning Sum MTC	.414	.171	.120	9.316**	.354**
es-MacGinitie					
Prior Knowledge MTC	.225	.051	.051	*ns*	*ns*
Questioning Mean MTC	.484	.234	.183	15.353**	.429**

e. MTC = Multiple Text Comprehension; PC = Passage Comprehension.
$< .05$; $^{**}p < .01$.

ble 14

ression Analyses of Prior Knowledge and Questioning on Two Text Comprehension Variables for Grade 3 Students

endent and Independent riables	*R*	R^2	ΔR^2	$F\Delta$	*Final* β
ltiple Text Comprehension					
Prior Knowledge MTC	.446	.199	.199	28.343^{**}	$.446^{**}$
Questioning Mean MTC	.516	.266	.067	10.275^{**}	$.271^{**}$
ltiple Text Comprehension					
Prior Knowledge MTC	.446	.199	.199	28.343^{**}	$.446^{**}$
Questioning Sum MTC	.523	.274	.075	11.628^{**}	$.300^{**}$
es-MacGinitie					
Prior Knowledge MTC	.415	.172	.172	25.155^{**}	$.415^{**}$
Questioning Mean MTC	.472	.223	.050	7.778^{**}	$.236^{**}$
es-MacGinitie					
Prior Knowledge MTC	.415	.172	.172	25.155^{**}	$.415^{**}$
Questioning Sum MTC	.440	.194	.021	3.194^{**}	*ns*

e. MTC = Multiple Text Comprehension; PC = Passage Comprehension; *ns* = not significant at $p = .05$.
$< .05$; $^{**}p < .01$.

Table 15

Reading Comprehension Scores for Grade 4 and Grade 3 Students as a Function of Prior Knowledge and Questioning

		Grade 3		Grade 4	
Multiple Text Comprehension		Prior Knowledge Low	High	Prior Knowledge Low	High
Questioning Mean					
Low	M	2.08	2.50	2.46	3.10
	SD	.78	.92	.76	.56
	n	49	8	26	10
High	M	2.49	3.50	3.00	3.25
	SD	.98	.81	1.14	1.28
	n	43	16	24	8
Multiple Text Comprehension					
Questioning Sum					
Low	M	2.05	2.67	2.74	2.89
	SD	.80	1.50	1.16	.92
	n	55	6	27	9
High	M	2.59	3.33	2.70	3.44
	SD	.95	.68	.76	.88
	n	37	18	23	9
Passage Comprehension					
Questioning Mean					
Low	M	.32	.41	.34	.53
	SD	.18	.20	.29	.21
	n	32	24	24	16
High	M	.34	.48	.33	.51
	SD	.20	.17	.19	.17
	n	29	20	13	15

Table 15 (continued)

Reading Comprehension Scores for Grade Four and Grade Three Students as a Function of Prior Knowledge and Questioning

		Grade 3		Grade 4	
		Prior Knowledge		Prior Knowledge	
Passage Comprehension		Low	High	Low	High
Questioning Sum					
Low	M	.34	.45	.36	.52
	SD	.21	.21	.26	.21
	n	36	25	19	19
High	M	.31	.44	.31	.54
	SD	.16	.17	.26	.16
	n	24	19	18	13
Gates-MacGinitie					
Questioning Sum					
Low	M	463.24	482.63	452.27	488.30
	SD	38.92	34.75	41.49	31.42
	n	54	8	22	10
High	M	469.02	502.44	481.40	484.38
	SD	26.46	28.79	32.94	23.74
	n	45	16	25	8
Gates-MacGinitie					
Questioning Sum					
Low	M	460.87	494.17	452.23	488.22
	SD	37.83	36.28	39.38	29.22
	n	61	6	26	9
High	M	473.89	496.39	487.00	484.89
	SD	24.41	31.04	31.07	27.43
	n	38	18	21	9

Table 16

Questioning Levels According to Levels of Multiple Text Comprehension for Grade 4 Students

Multiple Text Comprehension	Questioning for Multiple Text Comprehension: Low	High
Low	33	22
High	5	14

Note. The values represent frequencies of questioning categories (high/low).

Table 17

Questioning Levels According to Levels of Multiple Text Comprehension for Grade 3 Students

Multiple Text Comprehension	Questioning for Multiple Text Comprehension: Low	High
Low	48	29
High	15	33

Note. The values represent frequencies of questioning categories (high/low).

Table 18

Percentages of Questions for Multiple Text Comprehension (Mean Indicator) for Grade 4 and Grade 3 Students

	Grade 4	Grade 3
Mean Level	Percentage of Questions Asked	Percentage of Questions Asked
.0 - .9	10%	24%
1.0 - 1.9	70%	67%
2.0 - 2.9	18%	9%
3.0 - 4.0	2%	____

Table 19

Correlations of Prior Knowledge with Questioning and Reading Comprehension for Grade 3 and Grade 4 Students

	Grade 3		Grade 4	
	Prior Knowledge		Prior Knowledge	
	MTC	PC	MTC	PC
Questioning MTC				
Sum	.41**	.26**	.10	.27
Mean	.31**	.34**	.15	.40*
Questioning PC				
Sum	.16	.13	.23	.31
Mean	.01	.16	-.20	.06
MTC	.45**	.30**	.19	.30
PC	.38**	.33**	.34	.33**
Gates-MacGinitie	.41**	.36**	.23	.40**

Note. MTC = Multiple Text Comprehension; PC = Passage Comprehension.

Chapter VI
Discussion

My major purpose in this dissertation was to examine the relationship of student-generated questions with reading comprehension. The first step towards this endeavor was to investigate whether student questioning was correlated with different measures of reading comprehension. Results for the first hypothesis confirmed that there were several significant correlations among two indicators of questioning and three measures of reading comprehension for students in grades three and four respectively. Third and fourth graders' self-generated questions in relation to expository texts were coded into four levels of a Questioning Hierarchy. Levels varied in terms of the level of conceptual understanding the question requested. Two indicators for questioning were used, the average value of the levels of the questions asked (mean) and the sum of the levels of the questions asked (sum).

Students asked questions during two questioning tasks: the Questioning for Multiple Text Comprehension task and the Questioning for Passage Comprehension task. When students asked questions in relation to multiple texts on ecology, the questioning mean indicator correlated with reading comprehension across two measures of reading comprehension for both Grade 4 and Grade 3 students. The two measures of comprehension consisted of the Multiple Text Reading Comprehension task in which students read several expository selections on ecology, and a standardized measure of reading comprehension, the Gates-MacGinitie comprehension test. The other indicator of questioning, the sum, for the Questioning for Multiple Text Comprehension task correlated with the Gates-MacGinitie test for fourth and third graders, but only with the Multiple Text Comprehension task for Grade 3 students. On the other hand, when students' questions were assessed using the shorter questioning task, Questioning for Passage Comprehension, only the sum indicator correlated statistically significantly with the Passage Reading Comprehension task for Grade 4 students.

I further examined the relationship between questioning and reading comprehension by controlling for the potentially confounding variable of prior knowledge. Results for the second hypothesis showed that even when accounting for the contributions of prior knowledge, questioning accounted for a significant amount of the variance in reading comprehension. For Grade 4 students, one of the two questioning indicators accounted for significant amounts of variance, when controlling statistically for prior knowledge in all three of the text comprehension measures. These measures included the Multiple Text Comprehension package on ecology topics, the Passage Comprehension on an animal's survival and the Gates-MacGinitie comprehension test. Results for Grade 3 showed that both questioning indicators for the Questioning for Multiple Text Comprehension task accounted for significant proportions of variance in reading comprehension for multiple texts and for the Gates-MacGinitie test. However, neither indicator of questioning, when measured with the shorter Questioning for Passage Comprehension task, accounted for a significant proportion of the variance in the passage comprehension task when the variance contributed by prior knowledge was accounted for.

After finding empirical evidence that supported the relationship between questioning and reading comprehension, it seemed necessary to further investigate the relationship of these two constructs. For this purpose, the third hypothesis proposed that there would be an association between students' questions levels and students' reading comprehension levels. Results supported this hypothesis by showing an alignment between students' lower or factual questions (Level 1 in the Questioning Hierarchy) and lower levels of conceptual knowledge and between conceptual questions (Levels 2, 3, & 4 in the Questioning Hierarchy) and higher levels of reading comprehension. In other words, students who generally asked lower-level (factual) questions tended to comprehend text commensurate with the lower levels of the Knowledge Hierarchy, whereas students who asked higher-level questions (conceptual and interrelationship-probing questions) tended to have levels of reading comprehension that were rich in conceptual explanations, associations among facts and concepts and that depicted principled knowledge in ecology.

The overall results of this dissertation both confirm and expand the current literature in several ways. In the past, instructional research has shown that teaching students to ask questions in relation to text or in the framework of a reading activity influenced reading comprehension (Ezell, Kohler, Jarzynka, & Strain, 1992; Nolte & Singer, 1985; Raphael & Pearson, 1985; Singer & Donlan, 1982; King & Rosenshine, 1993; Scardamalia & Bereiter, 1992; Taylor & Frye, 1992). Even though the impact of questioning instruction had not always been easily isolated from the impact of instruction of other strategies (e.g., Palincsar & Brown, 1984), studies have pointed to students' improvement in reading comprehension as a result of questioning instruction. This influence was in the form of increased awareness of the main idea in a text (Wong & Jones, 1982; Palincsar and Brown, 1984; Dreher & Gambrell 1985), improved performance in standardized reading comprehension tests (e.g., Cohen, 1983; Ezelle et al., 1992; Rosenshine, Meister & Chapman, 1996; National Reading Panel, 2000), or experimenter-designed tests (e.g., Dreher & Gambrell 1985; Rosenshine et al., 1996; National Reading Panel, 2000), as well as in the form of positive associations between questioning and performance in basic skills in reading tests (Scardamalia & Bereiter, 1992). Most of this evidence has been the result of instructional interventions.

Even though these interventions consisted of questioning instruction, student questions were not frequently measured as a dependent variable. In the majority of these studies, elementary, middle, high- school and college students were taught to generate questions in reference to texts, but the impact of instruction was measured by assessing reading comprehension rather than questioning per se. For instance, third grade students showed significant gains on standardized and criterion comprehension tests after being taught to ask literal questions about stories (Cohen, 1983). Eleventh-grade students who were taught to ask questions about main character, setting, and plot in a story showed improved performance on an experimenter-designed multiple-choice test (Singer & Donlan, 1982). Fourth and fifth graders showed improvement on comprehension after being taught to ask story-specific questions (Nolte & Singer, 1985) and third graders who were taught to ask text implicit versus text explicit questions showed improvement in the California Achievement Test (Ezell et al., 1992). Furthermore, the majority of the questioning instructional studies reviewed in Rosenshine et al's (1996) meta-analysis included outcome measures consisting of standardized reading achievement tests, experimenter- designed comprehension tests, and students' summaries of a passage (Rosenshine et al., 1996).

On other occasions, besides comprehension tests, outcome measures included frequency of question types and number of questions asked. By looking at these variables, researchers tried to capture students' improved capacity to formulate questions after instruction. This has been the case for instruction of main idea questions. When eighth and ninth-grade students with learning disabilities were taught to ask main idea questions, their performance after instruction was measured as improvement in their awareness of main idea and number of questions asked about main ideas. Performance for normal-achieving students was also measured by improvement in asking main idea questions, as well as by performance in comprehension on a range of expository passages (Wong & Jones, 1982). In addition, impact of instruction of main idea questions was measured by sixth-grade students' ability to *answer* main idea questions versus detail questions about a text (Dreher & Gambrell, 1985), and by the number of main idea questions generated by seventh graders after receiving multiple strategy instruction (Palincsar & Brown, 1984). When questioning instruction consisted of literal versus inferential question types, students' performance was measured either by assessing their ability to ask and answer both types of questions (Davey & McBride, 1986) or by the number of questions asked for each type (MacGregor, 1988).

The examination of the outcome variables in most of the questioning-instructional studies reveals that, for the majority, questioning was either not measured at all or was not measured with a rubric beyond a simple high-low dichotomy. Rather, instruction was assessed by looking at students' performance in reading comprehension tests. When questioning *was* measured, it was through the number of questions taught during the intervention, as opposed to questions of another type, limiting the results to frequencies in most of the cases. Despite these limitations, the fact that outcome variables focused mainly on reading comprehension tests permits us to infer that most of these instructional interventions had an impact on reading comprehension. However, the rationale for that impact is unknown, it is not known why questioning instruction had a bearing on reading comprehension.

On the other hand, by measuring students' performance on reading comprehension, it is assumed that students' improvement on these tests is a consequence of questioning instruction. This assumption purports that a more thorough analysis of the text and retrieval of information could be achieved by asking "good" comprehension questions (i.e., main idea, inferential, or high-level questions). Although a tenable one, this assumption can be rivaled by other possible explanations. It could be that generating questions in relation to text may contribute to deep, active processing of the text. Asking questions about text may lead to elaboration of text or to finding causal explanations in text that, had questions not been posed, text would have been comprehended at a much more superficial level. It could also be that, as measured in some studies, number of questions could be related to better text comprehension. The higher the number of questions asked, the more inquisitive the reader and the greater his predisposition to inquire and learn about text. A third alternative is that students' exposure to instruction of two types of questions (e.g., literal versus inferential) could be responsible for the improvement in text comprehension. When asking questions in reference to text, readers are inquiring about different components of the text. If students are taught that types of questions lead to different answers in the text, they can learn to ask questions that focus on key ideas and central relationships in the text. These are processes that will enhance text comprehension. Lastly, the relationship between question instruction and improved text comprehension may be due to the impact that prior knowledge has on text comprehension. It could be that students' questions about a topic mainly reflect the students' prior knowledge about that topic, in which case, questions would not constitute a variable independent of prior knowledge.

Although researchers have supported some of these assumptions in their discussion of results, none of these studies presented empirical validation for them. In most of the questioning literature, it is assumed that the quality of reading comprehension is improved as a result of the instructional intervention on questioning. In other words, in most of these studies the assumption is that as the quality of questions increased (i.e., the number of inferential questions or the frequency of main idea questions), the quality of reading comprehension improved as a consequence. However, the evidence for this assumption has not been presented. Without measuring questioning as a variable, there is no empirical evidence to support the purported relationship between questioning and improved performance on reading comprehension tests.

Measuring students' questioning quantitatively requires the development of comparisons on a hierarchy or a rubric. In such a rubric, ascribing levels to questions according to their requests for information allows capturing differences among them. Concurrently, these levels permit the exploration of the empirical relationship of questioning as a reading strategy with other cognitive variables such as reading comprehension and prior knowledge. In the questioning literature, researchers have investigated the impact that teaching different question types may have on learning (e.g., Ezell, Kohler, Jarzynka, & Strain, 1992; Raphael & Pearson, 1985; Scardamalia & Bereiter, 1992). Some of these studies described question-types on the basis of the information requested, the processes involved in the responses they elicited (e.g., inferences, explanations, justifications, etc.) (Scardamalia & Bereiter, 1992; King & Rosenshine, 1993), prior knowledge (Scardamalia & Bereiter, 1992), and the degree to which questions were conducive to deep science understanding (Cuccio-Schirripa & Steiner, 2000).

The question hierarchies described in two of these latter studies (i.e., Scardamalia & Bereiter, 1992; Cuccio-Schirripa & Steiner, 2000) have significantly influenced the Question Hierarchy in this dissertation. Scardamalia and Bereiter (1992) approached their study of elementary school children's questions from two main perspectives: the source of the questions and the influence that the information asked by the question would have on knowledge building. The sources of the questions posed consisted of whether they were "text-based" or "knowledge-based". Both features were the conditions in which students asked questions in this study. The categorization of questions in relation to knowledge building was based on a four-category scale. Two categories of the scale included the relative contribution of the question to knowledge advancement (e.g., based on how much a question contributed to advance conceptual understanding) and whether the question requested factual or explanatory information. These two categories were expanded by incorporating them into the four levels of the Question Hierarchy in this study. Expanding each of these categories consisted first, of defining what type of questions consisted of factual versus conceptual requests and second, in characterizing what types of questions constituted advancement in conceptual knowledge (e.g., questions that request information about ecological concepts and/or ask about interrelationships among concepts in the domain of ecology). Describing these categories by means of specific question levels afforded the inclusion of a wide range of third and fourth graders' questions in a consistent way, as it was evident by the interrater reliability coefficients obtained for the Questioning Hierarchy. The other two categories in the Scardamalia and Bereiter's scale consisted of four-point ratings on the interest a question evoked in the rater and on the complexity of the information search required to answer a question. Neither of these categories was integrated into the hierarchy in this study.

The questioning scale developed by Cuccio-Schirripa and Steiner (2000) had a lesser bearing on the development of the current hierarchy. In this case, questions requesting simple, factual, and yes/no answers, as well as questions requesting classifications were the two major aspects that were used and on which I built upon to create the current hierarchy. In particular, these two categories were mainly included in the two lowest levels of the Questioning Hierarchy (i.e., Levels 1 and 2). However, as with the Scardamalia and Bereiter's scale, these categories were expanded when incorporated into the current Question Hierarchy. They were expanded by first, defining what "simple, factual" questions consisted of and second, by identifying what types of classifications/taxonomies in the domain of ecology qualified for a more global (i.e., Level 2 in the current hierarchy) or a more specific level (i.e., Level 3 in the current hierarchy).

Types of questions, then, have been integral to questioning instruction. In past studies, descriptions of these types has helped with understanding the instructional impact questions may have on learning at-large and reading comprehension in particular. However, these question types have not been often quantified in terms of hierarchical levels nor have they been quantitatively related to reading comprehension. Thus, as discussed, without a measurement of questioning it is unfeasible to identify questioning as the variable responsible for increasing reading comprehension.

The results of this dissertation contribute to the literature by expanding the understanding of student questioning as a quantifiable variable at least in four main ways. First, in order to measure students' questions in a systematic way a Questioning Hierarchy was developed. This hierarchy was composed by examining students' questions in relation to texts and by categorizing questions according to the quality of their requests for information in the domain of ecology. This process rendered a detailed question hierarchy that permitted describing and measuring student questioning. Few studies have attempted to identify student questioning as a variable. The Questioning Hierarchy presented in this dissertation is a useful tool to measure and describe student questioning as a cognitive variable. Additionally quantifying and isolating questioning as the variable of interest provides the empirical basis for a theoretical perspective on student questioning.

As it has been underscored in the past, research on student questioning in classrooms has been approached either from a "text-based" perspective or from a "knowledge-based perspective" (Scardamalia & Bereiter, 1992). Text-based questions have been described as questions produced on demand in response to certain clues and generated in relation to specific texts or topics. Knowledge-based questions have been defined as spontaneously generated and coming from students' background knowledge and experience (Scardamalia & Bereiter, 1992). In this study, students' questions shared both characteristics: they were generated in relation to specific text-topics, and they were also generated in conditions that allowed students to use their background knowledge or experience in their formulation. Both of these features are important because they maximize the range of questions students can ask about a topic, while still constraining them to ask questions in reference to a particular text. Having students browse the text for a brief time may have facilitated elicitation of students' background knowledge about the text-topic. At the same time, prompts for question asking did not compel students to answer the questions they posed. This may have given students more latitude for exploring their real inquiries about the topic, rather than being focused only on those questions they felt they could accurately answer. In their study, Scardamalia and Bereiter (1992) refer to the significance of having students explore what they need or want to know rather than to holding them accountable for seeking answers to the questions they ask (Scardamalia & Bereiter, 1992, p. 185). Although one of the goals of teaching questioning as a reading strategy may be to have students answer their own questions in order to foster deep interaction with the text, a study of student questioning such as this may benefit from having students simply ask questions geared toward what they desire to learn, without major emphasis on their answers. Such a context could encourage students to focus on what their real inquiries are while minimizing the risk of failure. Both of these aspects may help broaden the range of questions students pose in relation to text.

The range and type of questions asked may also be influenced by the illustrations in the text. Studies investigating the impact that pictures have on reading comprehension have revealed that the type of pictures in a text interacts with the comprehension ability of the students (Waddill & McDaniel, 1992). Detail pictures enhanced comprehension of specific details in the text for readers of different levels, but "relational" pictures (i.e., pictures depicting the main ideas or propositions in a story) increased recall of relational information in the text only for average and high skilled readers. Low-level readers could not detect causal relationships in stories, even when presented with pictures (Waddill & McDaniel, 1992). The two text-types in this study include concept-illustrative pictures (e.g., a pair of stallions fighting for control of a zebra family), as well as detail-illustrative pictures (e.g., number of water lilies growing on the Amazon River). If the impact of these pictures on the questions asked by high and low questioners were similar to the effects found for pictures on reading comprehension, detail pictures would benefit questioning for both high- and low-level questioners. However, pictures capturing essential concepts in the text would mainly benefit students asking conceptual questions, since those students would focus on those relational aspects of text. Furthermore, since all pictures in these texts were accompanied by captions, it is difficult to speculate on the role of the pictures in isolation. This is so because there is a high probability that higher comprehenders /questioners would have read those captions more often while browsing the text than the lower questioning group. That is, for text containing pictures with captions it is possible, but unlikely, that the lower questioners would have an advantage over the higher questioners.

The role of questions in reading comprehension can as well be related to the "self-explanation effect" reported by Chi et al. (1994). Self-explanations and self-generated questions are both opportunities for the reader to integrate information across text and to make inferences from text. Self-explanations elicit inferences that go beyond the text (Chi et al., 1994). Self-generated questions, as long as they are not limited to factual, Level 1 questions, elicit integration of information across text sections as well as inferential answers by having the reader induce information to answer conceptual questions. A major difference between self-generated questions and self-explanations is that questions, as hereby described, do not get answered at the time they are posed, whereas self-explanations consist of a process of reorganization of information during reading. To elicit self-explanations, students were prompted to explain what each sentence in a biology text meant. Students received specific, as well as general clarification prompts throughout the 101-sentence passage. The process of self-explanation consists of multiple components including: (a) establishing connections between portions of text by reviewing previous sections in the text, (b) creating inferences, (c) reorganizing newly learned information and, (d) constructing an explanation of a segment of text. Questioning as a reading strategy, as defined here consists of students asking questions in reference to text after having briefly interacted with that text, but with no access to text during question generation. The process of generating questions in advance of reading a text emphasizes the inquiry, the request for information about a topic, not the understanding of information after reading it. In a way, self-explanations and questions serve to infer and integrate information in texts. However, self-explanations do so by delving into information after parsing and analyzing text, whereas self-generated questions anticipate relations within the text by virtue of the quality of the requests made. Because this was not an intervention study, the quality of questions asked by this sample of students was not bound to a particular text and could be described as a generalizable competence of the child in the domain of ecology. The impact of self-explanations described by Chi and colleagues (1994), on the other hand, appears to be more restricted by the quality of understanding of the text provided.

Second, a measure of student questioning allowed investigating the contribution of questioning to reading comprehension, independent of the contribution of prior knowledge. It was found that the impact that student questioning had on reading comprehension in the domain of ecology was above and beyond the contribution that prior knowledge made to comprehension. In this sense, this finding contributes to ruling out the assumption that questioning and prior knowledge could be overlapping variables. Furthermore, it was found that questioning had an impact on reading comprehension irrespective of the level of prior knowledge**.** That is, results supported the view that questioning contributed to increment reading comprehension for students with high prior knowledge as well as for students with low prior knowledge. In addition, having measured student questioning with two different types of texts and with two different measures of prior knowledge allowed speculation on the varying characteristics that questions might present when asked in relation to texts of different scopes. I would like to elaborate on this point next.

Results indicated that the longer, questioning for multiple texts task was predictive of reading comprehension when compared to the shorter, passage-questioning task. In the multiple-text questioning task, students browsed a package containing texts on ecology topics organized in multiple chapters. Students browsed the package for several minutes and were then prompted to ask questions about the life of plants and animals in the two biomes. In the questioning for passage comprehension task, students were prompted to ask questions after browsing a three to four-page passage on an animal's survival. For both tasks students asked an average of 8 to 10 questions.

Among the plausible reasons that can explain the higher association of questioning with the multiple-text comprehension task when compared to the shorter questioning task is the scope or breadth of the text. It is possible that the scope of a text influences the number and type of questions a reader asks. Longer, more elaborate texts that cover broader topics, might offer more possibilities for reflecting knowledge domain than texts that are narrower in scope and comprise more limited topics. It is likely, then, that the scope of the text facilitates or hinders the activation of prior knowledge in a domain, while simultaneously eliciting a broader or a more restricted range of questions. Furthermore, a text that is broader in scope may predispose the reader into a more inquisitive approach by force of its length, depth, and the range of topics it covers than a more focused text. The combination of these text factors may impinge on the type and number of questions a reader asks in relation to that text. As it pertains to this study, a text with topics such as animal and plant life in two biomes (Multiple Text Comprehension task) may lend itself to a broader range of questions than a topic such as a single animal's survival (Passage Comprehension task) with the questions for the latter topic being more limited in type and number. Whether the scope of the text is a sufficient explanation for the absence of a correlation between questioning and passage-reading comprehension for third grade students in this study remains speculative at the moment and a subject for future research.

Indeed, a perusal of the correlations (see Table 11) among the two questioning tasks and the three reading comprehension tasks contribute to explain this pattern of relationships further. When looking at the correlations among these variables across grades, there is a total of six possible correlations when taking into account both questioning indicators and the three reading comprehension tasks. For example, the sum indicator for Questioning for Multiple Text Comprehension can be correlated with Multiple Text Comprehension, Passage Comprehension, and the Gates-MacGinitie test for grades three and four respectively. The examination of these sets of correlations shows that across both grades the questioning mean indicator for Multiple Text Comprehension was the only variable that consistently correlated with all three reading comprehension measures at a significant level. The questioning sum indicator for Multiple Text Comprehension correlated four out of six times with the reading comprehension tasks across both grades. The questioning sum indicator for Passage Comprehension correlated two out of six times with the reading comprehension tasks. The questioning mean indicator for Passage Comprehension correlated one out of six times with the reading comprehension tasks. These patterns of correlations reveal that of all the questioning variables, the questioning mean for Multiple Text Comprehension was the only one that systematically correlated with all three measures of reading comprehension across both groups of students.

Implications from these results are related to the complexity of the task and the type of questioning indicator. On one hand, the complexity of the task is intimately related to the scope of the text discussed earlier. On the other hand, the complexity of the task refers to the topic and the use of strategies. The use of reading strategies implies a deliberate and effortful approach to reading. Generating questions in relation to an extensive text, such as the one presented to students for the Multiple Text Comprehension task, is a cognitively demanding activity that requires a minimum amount of time and effort to be performed fairly well. It is plausible then, as with other reading strategies, that questioning can be better deployed with complex tasks rather than with simpler, shorter tasks. A complex task, in this case, implies depth and breadth of text and topics. Like with a broad text scope, there is the possibility that questions could be more easily elicited if the topic is broad enough to facilitate access to a knowledge domain (i.e., ecology) and if the use of strategies within that knowledge domain can be facilitated. If this is the case, one can speculate that the broader topic of two biomes in the domain of ecology may elicit higher quality questions than a more restricted topic or a simpler task such as the Questioning for Passage Comprehension.

The second implication of these results is related to the nature of the questioning indicator: the mean. The mean, calculated as the average level of the questions asked, represents the best estimate of a student's conceptual level in questioning. The mean captures the on-hierarchy questions as well as the non-codable questions (coded 0).The sum, on the other hand, consists of the addition of the on-hierarchy question levels. As such, the sum indicator adds to the score when the student asks a large number of low-level questions, thereby increasing its value; conversely, the value for the mean decreases with a large number of low-level questions. The sum, then, can include variance represented by a high number of low-level questions, whereas the mean is a better indicator for capturing the values of a few conceptual higher-level questions.

The correlations of the mean indicator for Questioning for Multiple Text Comprehension with a measure of students' reading comprehension in the same topic for which questions were posed, as well as with reading comprehension in two other topics, lend support for the generalizability of the task and the indicator of questioning. In other words, the generalizability of the correlations to three reading comprehension tasks across two age groups may reflect that the typical performance in questioning for these ages is represented by the average question level (mean indicator) in reference to a complex task (given by a broad text scope and topic).

The third contribution of this study is related to the patterns of questions asked by the two grades in the sample. An empirical examination of questioning permitted comparing results across third and fourth graders to find that there were some developmental differences in the question types generated by these two groups. Firstly, the mean for Questioning for Multiple Text Comprehension was higher for fourth graders than for third graders, showing that the average level of questioning was higher for the older questioners. Secondly, even though the majority of the questions asked by both groups were between Levels 1 and 2 of the Questioning Hierarchy, fourth graders asked twice as many above Level 2 questions than Grade 3 students. Also, Grade 4 students asked a small amount of Level 4 questions compared to none for Grade 3. Although these findings are limited to questioning for these two age groups, they constitute a first attempt to examine developmental differences in self-generated questions in elementary school students.

Fourth, measuring question levels and relating them to levels of reading comprehension lays the ground for a theory of questioning as a reading strategy. The alignment found between question levels and levels of text comprehension constituted an approximation to the explanation of *why* the quality of questioning had an impact on reading comprehension. Empirical evidence showing that conceptual levels of questions were commensurate with conceptual levels of reading comprehension provides a plausible rationale for the influence of questioning on reading comprehension. In previous studies, different assumptions were made for the influence that instruction on question-generation had on reading comprehension and on the acquisition of deep, principled knowledge in a domain. The alignment between question levels and levels of conceptual knowledge built from text does not rule out alternative explanations for this relationship, but represents empirical support for the instructional effects of previous studies. Results in this dissertation showed that question types are differentially related to levels of text-comprehension. If higher conceptual questions are associated with levels of conceptual knowledge, questions that request information organized at a conceptual level in a knowledge domain may create the predisposition to comprehend information organized at that level in that domain. As van den Broek and Kremer (2000) suggested, an understanding of the role that students' questions play in comprehension can be advanced to the extent that questions request information that support the building of a network that includes the main concepts and relationships within that text. Although other viable explanations for the role that student-questioning may play in reading comprehension are not ruled out by these results, they lend support to the notion that the quality of questions expressed in inquiries about concepts and their interrelationships may be an element that explains the relationship of questioning to reading comprehension.

However, even though the conceptual quality of questions can explain some of the variance in reading comprehension, there are several alternative sources of variability that could influence reading comprehension. These multiple determinants of variability in reading comprehension could be confounded with questioning ability. Even though, in this study I did not try to define a construct such as "questioning-ability", it was assumed all along the study that there is an “ability” or a capacity that can be described as question generation. Self-generated questions as described and measured in this study consisted of students’ questions posed in reference to a text during an “open” task in which students could ask questions about topic of the text. The task was open in the sense that students could ask any type of questions, with the sole constraint of being about the topic and text they had previously browsed. This open format allowed capturing students’ *self-generated* questions and described these at length. However, as with any study that attempts to describe a new variable, the limitations given by multiple confounds is present. In other words, performance on questioning could be related to multiple variables that could independently account for variance in reading comprehension. Some of these variables are motivational in nature, such as the interest, or curiosity to read about a specific topic which could be expressed in amount of books and time spent reading as well as the types of questions posed. Other variables are intrinsically related to the cognitive demands involved in the process of reading comprehension. Such variables could include vocabulary, syntactic knowledge, causal understanding and inferencing.

Vocabulary could be a determinant of variability in reading comprehension. Both, the reader’s vocabulary and the text vocabulary load interact with the reader’s topic knowledge and the comprehension of the text. The relation between vocabulary knowledge and reading comprehension is very complex because it is confounded by factors such as conceptual and cultural knowledge, and instructional opportunities (Snow, 2002). Furthermore, there is considerable agreement among researchers that reading is a significant contributor of vocabulary growth (for a review see Stanovich, 2000). However, there is also speculation that the association between variability in vocabulary knowledge and reading achievement may be a good candidate for a strong reciprocal relationship (Stanovich, 2000, p.183).

Children's vocabulary knowledge can also be a source of variance in questioning. The child with limited vocabulary knowledge will have difficulty expressing thoughts and ideas in statements as well as in questions. Restricted word-choice may become a significant hindrance when trying to formulate specific questions about a topic which require elaborate language expressed in knowledge principles within the question itself. Furthermore, for the child who is struggling with a limited vocabulary, it is highly probable that composing an idea in the form of a question is even more difficult than formulating this in a statement. Conversely, having a rich and extended vocabulary will most probably facilitate the formulation of questions, since ideas would be more easily expressed in interrogative format. In summary, just like vocabulary knowledge can be a factor facilitating or hindering children's reading comprehension, word-choice manifested in a large –or limited- expressive vocabulary could be a source of variability in the ability to ask questions about a topic. The difference between reading comprehension and questioning in reference to vocabulary may reside in the facilitation given by context during reading. During reading, students can make use of context to derive word- meanings, whereas when prompted to ask questions about a text they had briefly browsed, students are circumscribed to their own expressive vocabulary and cannot resort to context. Questioning, then, relies on vocabulary to the extent that formulating a question necessitates precise or specific terms in order to clearly convey the content of the question. However, as a cognitive process, self-generated questions can be said to rest equally upon world knowledge, topic prior knowledge, reasoning skills etc., all cognitive attributes that can help with question specificity. Thus, vocabulary is an important attribute of self-generated questions, but the ability to generate questions in relation to a topic does not depend fully on the vocabulary knowledge of the questioner. Nevertheless, research that examines the relationship between vocabulary knowledge and questioning can shed some light onto views that are merely speculative at the moment.

Students also differ in their syntactic knowledge. The ability to use clauses within single, more complex constructions requires language development and appropriate instruction. Students who are limited in their knowledge of syntax, either because of language impairments, second-language issues or even due to poor instruction will struggle with the understanding and use of complex grammatical constructions such as embedded clauses. This limitation in syntactic knowledge will be reflected in their text comprehension.

Successful comprehension resides on various operations involved in reading such as concentration on the task at hand, use of reading strategies, constructing a propositional base, and also the ability to parse text syntactically (Snow, 2002). Thus, knowledge of syntax is another source of variability in reading that will be expressed in a reader's capacity to comprehend a variety of texts. At the same time, syntactic knowledge will impinge on a child's ability to formulate questions. High-level questions, often, require complex grammatical constructions such as conditional clauses of the type of "If this happens to *X*, what will happen to *Y*?" The child who is not comfortable in using these constructions in her everyday language, or at least in general statements, will be limited in using them when asking questions in reference to a school-related topic.

Variability in questioning, then, could be affected by syntactic knowledge or the fluency and conscious control that a child has over complex grammatical constructions. However, a key difference between self-generated questions and syntactic knowledge resides on the fact that a student could still ask high-level conceptual questions using simple grammatical structures. An example would be: *What is the food chain of …?* where no embedded clauses are contained in the question, but still a conceptual, sophisticated relational answer is needed. Therefore, although knowledge of syntax is an important factor in the ability to formulate questions, high-level conceptual questions can be framed with simple grammatical structures and still request elaborate explanations.

Another source of variability in reading comprehension can be causal understanding. Causal understanding, or the ability to understand why things or events occur in a particular way, has been characterized as intrinsically related to comprehension of narrative texts. In particular, causal understanding has been linked to the ability to build networks of causal relations between events in a story (Trabasso, Secco, & van den Broek, 1984).

Causal understanding can also share dimensions of variability with self-generated questions. The ability to establish causal connections between ideas can be strongly related to high-level questions especially those being characterized as *why* questions. *Why* questions generally inquire about reasons or causal explanations. Deducing connections between causal antecedents and their consequences is an important form of reasoning that can be thought as subsumed by the cognitive processes involved in high-level questioning. In order to ask *why* something occurs it is necessary to know first that a certain event occurs in a given way and second, that there may be a reason for the event taking place in that particular way. Thus, posing high-level, *why* questions requires combining the knowledge of the antecedent (i.e., the event occurring under given circumstances) and anticipating that there is a rationale for the event occurring that way. Questioning, though, can be differentiated from causal understanding, because there is a skill involved in question formulation that is not present in causal thinking: The cognitive leap that goes from anticipating a reason for events occurring in a given way to the ability of putting these thoughts in a set of propositions that represent a question.

A similar line of argument can be built for variance accounted for inference-making in text comprehension. Kintsch (1998) distinguishes between two types of inferences in the process of reading comprehension. One type has to do with "…knowledge retrieval processes in which a gap in the text is bridged by some piece of preexisting knowledge that has been retrieved" (Kintsch, 1998, p.189). With this type of inference, knowledge is retrieved from long -term memory and added to the information in the text. The second type of inferences, what Kintsch (1998) defines as "proper inferences", consist of generation of new information derived from text information. The contrast between these two types of inferences is on whether the information used is pre-existent and retrieved from long term memory (first type) or if causal connections are used between two propositions in the text to generate the necessary new information (second type). Either type of inference can be claimed to account for variance in self-generated questions. High-level questions, especially, Levels 3 and 4 in the Questioning Hierarchy can be described as resting upon the process of inferencing. To formulate Level 3 and Level 4 questions students need to use prior knowledge (Level 3), and express principles of ecology within the question (Level 4). Both question levels, then, necessitate of pre-existent information as well as of causal connections to be formulated, both processes involved in inference-making. However, as it is the case with causal understanding, inferencing is a necessary, but not a sufficient condition for question generation. The process of generating a question may involve inference making, but it also requires the ability to use prior- knowledge and logical thinking to probe for further, new information. A unique aspect of questioning relies on the ability to use prior-knowledge, or new information extracted from text, to deepen knowledge by means of expressing this in a request for further information.

Limitations

There are at least two limitations to this study. First, generalizability of the results is limited to questions for information texts. In this dissertation, questioning was investigated in relation to information texts within the domain of ecology. Therefore, it is not known how questioning for narrative texts would relate to reading comprehension of stories. Although there are multiple studies that examined student questioning for narrative texts, they are limited by the absence of a detailed description of question types and how these relate to text comprehension. This limitation is not overcome by the present study. Furthermore, the two text-types used to elicit questioning in this study were based on authentic information texts for elementary grades. Rich-informational text and vivid pictures characterize these texts. Therefore, conclusions regarding student questions are applicable to these particular types of texts. It is not known if these findings apply to texts without pictures and with other text features.

Second, results of this study are limited to the description and categorization of questions of third and fourth graders only. Perhaps the Question Hierarchy can be applied to questions generated by students in later elementary grades, but its scope may be too limited to describe questions formulated by middle and high school students.

Future Research

The present study suggests that the quality of students' questions predicts reading comprehension even when prior knowledge is controlled for. Furthermore, results supported the view that the conceptual quality of questioning is commensurate with the conceptual quality of student reading comprehension. These findings provide the basis for an explanatory framework of the relationship between student questioning and reading comprehension. However, because this is a descriptive study, its implications need to be tested within instructional research in order to claim impacts of questioning instruction on reading comprehension. The vast majority of the studies in student questioning have been instructional interventions. However, as discussed, most of these studies have not tested the assumptions for the impact of questioning instruction on students' improved reading comprehension. To obtain a complete picture of the effects of questioning as a reading strategy on reading comprehension, it is necessary to explore the role of questioning from an instructional perspective.

The results of this study have important implications for educational practice. Findings suggest that students ask a variety of questions in relation to texts, and that those questions can be categorized according to levels or types. A future study could address whether these question levels are feasible to be taught and how this could be done. Such a study could explore the impact of training in question-generation on reading comprehension performance with an experimental design using three conditions. These conditions could consist of Question Training (QT), Question Generation Practice (QP), and No Question/Control (QC). Students in QT could receive question training according to the four levels of the Questioning Hierarchy presented in this dissertation. The QP group could interact with text by asking questions and answering them. In the QC group, students could interact with text by spending time reading the text materials, thinking about relationships and important ideas, and completing a vocabulary activity. The effects of instruction could be measured by comparing students on a measure of student questioning and a measure of reading comprehension. To control for students' differences in prior knowledge, a measure of prior knowledge could be used as a covariate. An experimental design like this will allow observing whether instruction that is based on the levels of the Questioning Hierarchy works for a elementary school students and how this instruction can be improved and tailored to students' take up and understanding of the levels of the hierarchy.

Appendix A

Ecological Concepts

Science Concept	Traits, behaviors or features encompassed by the concept
Reproduction: All plants and animals have behaviors, traits, and adaptations designed to insure reproduction of its species.	Egg Laying, Mating, Sexual Communication
Communication: Critical to all aspects of the life of plants and animals.	Songs/Chirps/Odors/Chemicals/Patterns/Colors/Shape/ Behavior
Defense: All plants and animals must have adaptations for defense from predators, enemies and the environment in order to survive.	Types of Bodies/Types of Appendages/Camouflage/ Warning Colors/Mimicry/Where in the Habitat They Live/How They Move/Scales/Shell/Teeth/Movement in Groups/Eyes
Competition: Because most critical resources are shared and in limited supply competition in plants and animals is often observed.	Conflict/Amount of Available Food/Size of Organisms/ Feeding Preference (Specialization on Food Type or General Feeder/Morphological or Behavioral Adaptations
Predation: While feeding on plants is very common, predation is a frequently observed interaction among animals.	Chasing or Seeking Other Animals/Running or Hiding/Behavioral Adaptations for Chasing, Seeking Other Animals, Running, or Hiding/Types of Mouths and Feeding/Types of Bodies/Types of Appendages/ Camouflage/Warning Colors/Mimicry/Where in the Habitat They Live/How They Move/Teeth
Feeding: The search for food and the interactions involved in feeding are critical if animals and plants are to acquire the nutrition needed for growth and development.	Teeth/Location in Habitat/Response to Other Animals/Eyes
Locomotion: Locomotion allows organisms to undertake all needed requirements of life and usually reflect a close	Feet/Fins/Tail/Ways of Swimming/Suction Cup/Webbed Feet

adaptation to their habitat.	
Respiration: Respiration is an essential process for the acquisition of oxygen, without most life cannot proceed.	Gills/Lungs/Skin
Adjustment to Habitat: Physical and behavioral characteristics of plants and animals that enable them to survive in a specific habitat.	Physical and behavioral characteristics of plants and animals that enable them to survive in a specific habitat- penguin has webbed feet; polar bear has thick fur; camels can store water
*Niche: Function of a species in a habitat through the use of resources and its contribution to other species' survival.	Function of species- dam building/ recycling/ scavenging/ population control/ habitat conservation

Knowledge of these ecological principles has different layers, with concepts, content, and supporting information about science phenomena.
*In Grade 4 the concept of *niche* replaces *respiration*.

(Adapted from CORI, Concept Oriented Reading Instruction, Guthrie, J.T., 2002)

Appendix B

Questioning Hierarchy for Ecological Science Texts

Level 1: Factual Information
Questions are a request for a factual proposition. They are based on naïve concepts about the world rather than disciplined understanding of the subject matter. Questions are simple in form and request a simple answer, such as a single fact. Questions refer to relatively trivial, non-defining characteristics of organisms (plants and animals), ecological concepts or biomes.

Text about animals. These questions may inquire about or take the form of:

- Commonplace or general features of animals that require simple factual answers or yes/no answers: *How big are sharks? Do sharks eat trash? How long are sharks teeth? How much do bears weigh?*
- Simple classification that only requires a yes/no type of answer or a one-word answer: *Are sharks mammals? Is there any place where you can't find sharks? What is the biggest shark? Are there male and female sharks?*
  These questions are characterized by yes/no answers, and additionally they are <u>not</u> concept-related, i.e. the predicate of the question is not concept-related.
- Questions that reveal either naïve knowledge, basic background knowledge or no knowledge of the topic: *Can they flip? Why do sharks bite some people? Are sharks pets? Do polar bears eat a lot of reindeer?*
- Coherent questions that are <u>not</u> relevant to the text topic (e.g. shark survival): *How can you get away from sharks? How do you protect yourself if a shark is coming toward you? How long have ponds been around? Are there any theories about polar bears?*

Text about biomes and organisms. These questions may inquire about or take the form of:

- Commonplace or general features of a living organism (plants or animals) in the biome. These questions request simple factual answers (e.g., numeric) or yes/no answers. *Do horses live in deserts? Do jellyfish live in rivers? Are there crabs in a river? How old do orangutans get?*
- Simple classification or quantification that only requires a yes/no type of answer or a one-word answer. The classification might inquiry about organisms or the biome itself. *Are monkeys mammals? How many grasslands are there? How many rivers are there in the world? How many plants live in ponds?*
  Note that these questions ask about *how many* organisms of a species live in a biome or *how many* biomes exist. They do not inquire about *types* or *kinds* of

organisms or biomes. Asking about kinds or types denotes classification or taxonomies that would characterize the question as Level 2.

- Commonplace or general features of the biome itself that are *not* defining attributes of the biome. *How deep are rivers? How big do rivers get? How big are grasslands? How do rivers get water in them?*
- Coherent questions which are not necessarily relevant to the text topic. *Can prairie dogs be pets? Is there any population in deserts?* (i.e. referring to people)
- Vague questions that do not address the text topics or the biomes specifically. *How many yellow animals are there? Are there animals in the water? Why is there grass?*
- Geographic location of biomes or organisms within biomes. Question is general enough not to request a classification. *Where are the deserts? Do polar bears live anywhere besides Antarctica? Where is the Indian Ocean?*

Level 2: Simple Description

Questions are a request for a global statement about an ecological concept or an important aspect of survival. Questions may also request general information that denotes a link between the biome and organisms that live in it. The question may be simple, yet the answer may contain multiple facts and generalizations. The answer may be a moderately complex description or an explanation of an animal's behavior or physical characteristics. An answer may also be a set of distinctions necessary to account for all the forms of species or to distinguish a species' habitat or biome.

Text about animals. *These questions may inquire about or take the form of:*

- Ecological concepts in their global characteristics. Usually the question inquires about *how* and *why*, so an explanation can be elicited. *How do sharks mate? How do sharks have babies? How do birds fly? How do bats protect themselves?*
- A global distinction to classify the animal as a type of species or types of organisms (general taxonomy). *How many types of bats are there? What kinds of sharks are in the ocean?*
- A global distinction about the animal's habitat or biome. *What types of places can polar bears live? What kinds of water do sharks live in?*
- Simple description of an aspect of an ecological concept. *How many eggs does a shark lay? How fast can a bat fly? How far do polar bears swim in the ocean?*

Text about biomes and organisms. *These questions may inquire about or take the form of:*

- Classification or taxonomy of organisms (plants or animals) that live in the biome. The specification of the organism living in that biome is explicit in the question: *What kind of algae are in the ocean?* rather than: *What types of algae are there?* (i.e. biome is not specified in the question). *What bugs live in the* *desert? What was the first animal in the river? How many endangered species are in the grasslands?*

- Global explanation or description of an ecological concept in reference to organisms that live in the biome. Usually the question inquires about *how* and *why*, so an explanation can be elicited *How do desert animals live? How do grasslands get flowers and trees?*
- Features or characteristics of the organisms that live in biomes that may include brief descriptions or references to ecological/biological concepts. *How often do water lilies grow in ponds? Where do tortoises live in the water? What do fish eat in rivers? Do lions ever try to bite zebras? Why do beavers have big wet tails?*
- Description of origin or formation of biomes: *How did deserts develop? How do ponds form? Where did oceans come from?*
- Description or explanation that involves or makes reference to a defining* or critical attribute of a biome. *How come it almost never rains in the desert?* (i.e. reference to dryness); *How long do sandstorms last?* (i.e. reference to a sandy region); *Why do rivers start at a hilltop? What makes rivers fast and flowing? Do grasslands have short or long grass? How come it always rains in the rainforest?* Note that two or more questions might have the same surface structure (i.e. question form) yet the content they inquire about might classify them as different question levels. For this particular definition a question might be tapping at a defining feature whereas another with the same question form might be just asking about a trivial attribute. For example the questions *How big is a river?* and *How big is an ocean?* will end up being in different levels due to the fact that size is not a defining feature for rivers but it is for oceans, thus the former question is coded Level 1 and the latter is coded Level 2.

* Defining or critical attributes of biomes are included in their definitions (see biomes definitions in this rubric)

Level 3: Complex Explanation

Questions are a request for an elaborated explanation about a specific aspect of an ecological concept with accompanying evidence. The question probes the ecological concept by using knowledge about survival or animal biological characteristics. Questions use defining features of biomes to probe for the influence those attributes have on life in the biome. The question is complex and the expected answer requires elaborated propositions, general principles and supporting evidence about ecological concepts.

Text about animals. These questions may inquire about:

- An ecological concept of the animal interacting with the environment. The question probes into a specific concept by showing prior knowledge on a significant aspect of the interaction. The question may for example focus on a

behavioral pattern that is typical of the ecological concept. *Why do sharks sink when they stop swimming? Why do sharks eat things that bleed? How do polar bears keep warm in their den?* Alternatively, the question can address physical characteristics that enable the interaction or biological process to occur. *Why do sharks have 3 rows of teeth? Why is the polar bear's summer coat a different color? Why do all bats have sharp teeth?*
Note that some of these questions have a surface structure (i.e. question form) that corresponds to a yes/no or one-word answer (Level 1), yet the question's deep structure (i.e. content asked for) reflects reference to an ecological concept which is clearly probed within the question. For example: *Do polar bears eat all the whale or do they save some? Do baby polar bears eat the same things as their mothers do? Do owls make their nests in cactuses?* The fact that the surface structure would classify the question as Level 1 is secondary to the fact that the question is concept-oriented and the nature of the answer expected is not a yes/no type of answer but rather an elaboration of the aspect of the concept being probed. In other words, these questions have an implied request for a conceptual explanation this is why they are categorized as Level 3 question.

- Requests a distinction among types of organisms within a species to understand the concept at hand. Either information about the ecological concept or the animals' interaction with the environment is used as the basis of the analytical process, e.g. What kinds of sharks lay eggs? What kinds of bats hide in caves? <u>or</u> the question may be directed to a structural or a behavioral characteristic necessary for the concept to be understood, e.g. How big can a great white shark's tooth be? Do fruit-eating bats have really good eyes? Do owls that live in the desert hunt at night? <u>or</u> the requested distinction may also refer to the types of habitats used by the organism e.g. Why do sharks live in salted water?

Text about biomes and organisms. *These questions may inquire about:*

- Description or explanation of an ecological concept of an organism that lives in a biome, with probed information about the organism <u>or</u> the biome. The question denotes prior-knowledge by including a level of specificity not included in questions in Level 2. The question may for example focus on a <u>behavioral</u> pattern that is typical of the ecological concept. *What kinds of animals <u>that eat meat live in the forest?</u> Why do <u>Elf Owls make their homes in cactuses</u>?*
- Description or explanation that involves or makes reference to a <u>defining</u> attribute of the biome where a major qualification of the defining attribute is implicit (or might be explicit) in the question. *Can you dig a water hole in the desert?* The question is asking for a complex characteristic (i.e. how far is the water?) in relation to the defining attribute (i.e. dryness).
- Explanation of the <u>influence</u> a defining feature of the biome has on life (animals and plants) in the biome. The question is not just inquiring about the defining feature itself as in Level 2 (e.g. *What makes the river fast and flowing?*) but on the

effects the defining feature has on the biome: *How do animals in the desert survive long periods without water? When it is hot in the desert, how can animals get so active?*

- Vague relationships between the biomes in reference to one concept. *Do river animals eat grass from the grasslands?*

Level 4: Pattern of Relationships

Questions display science knowledge coherently expressed to probe the interrelationship of multiple concepts, the interaction with the biome or interdependencies of organisms. Knowledge is used to form a focused inquiry for principled understanding with evidence for complex interactions among multiple concepts and possibly across biomes. Answers may consist of a complex network of two or more concepts.

Text about animals. These questions may inquire about or take the form of:

- Descriptions of animals' survival process in which two or more ecological concepts are interacting with each other. It includes probes for particular aspects of the animals' interactions.
  Do snakes use their fangs to kill their enemies as well as poison their prey? Do polar bears hunt seals to eat or feed their babies? How can the mother shark swim when the baby is attached to the cord after being born?

Text about biomes and organisms. These questions may inquire about or take the form of:

- Description or explanation of an organism's biology in which two or more ecological concepts are interacting with each other and references to the organism's biome (or other biomes) are made. *Why do salmons go to the sea to mate and lay eggs in the river?* The concepts might not be explicitly referred to, but the answer will elicit relationships among concepts. *How do animals and plants in the desert help each other?*

- Description or explanation of the interaction of two biomes in relation to an organisms' survival. *How does the grassland help the animals in the river? How are grassland animals and river animals the same and different?*

- Alternatively, the complexity of the question might lie in the inquiry for relationships of multiple organisms in relation to a single concept. *Is the polar bear at the top of the food chain?* The scope of the answer to this question is vast since the relationships among multiple organisms are described in reference to one concept (i.e. feeding).

Text on Biomes

Biome Definitions

Desert: A desert is an area that receives very little rain (rarely more than 20 inches per year) has extreme temperatures (usually very high temperatures) that fluctuate widely over the course of a day. Deserts cover about one-fifth of the earth's surface. Most deserts are very hot, but cold deserts also exist. Hot deserts, such as the Sahara Desert in Africa, have very high temperatures during the day and very low temperatures at night. Cold deserts, such as those in western Asia, are cold both night and day.
Deserts are characterized by low plant abundance with dry rocks or sands. Trees are usually absent.
Plants that grow in hot deserts are specially adapted to the lack of rainfall. Desert plants retain water in their seeds, roots, and thick stems. Many desert plants have spreading roots that grow very close to the surface, enabling the roots to absorb water quickly, before it evaporates.

Animals that live in the desert, including lizards, rodents, snakes, kit foxes, jackrabbits and spiders, are usually most active at night, or at dusk and dawn. During the day, they escape the heat by staying in underground burrows, hiding under rocks, or staying in the shadows of plants. Many desert animals get their water from their food, including plants that have water stored in them.

Grassland: Grasslands are areas dominated by plants known as grasses, and which lack other types of taller plants such as trees and shrubs. They generally occur in areas where there are large seasonal temperature extremes and relatively low precipitation. Areas are maintained as grasslands because of frequent fires, browsing by animals and periodic droughts. Trees are uncommon in grasslands because of low rainfall, frequent fires, and browsing by animals.

Grasslands were once abundant in central North America, South Africa, Argentina, Uruguay, and Russia, but many have been cultivated and are now farmland. Some of the animals that live in the remaining grasslands are gazelles, bison, wild horses, lions, wolves, prairie dogs, jack rabbits, deer, mice, coyotes, foxes, skunks, badgers, blackbirds, grouses, meadowlarks, quails, sparrows, hawks, owls, snakes, grasshoppers, leafhoppers, and spiders.

Forest: Forests are areas dominated by a dense growth of trees and other woody vegetation. Tree-dominated forests can occur wherever the temperatures rise above 10° C (50° F) in the warmest months and the annual precipitation is more than 200 mm (8 inches). They can develop under a variety of conditions within these climatic limits.

Trees create a complex structure in the forest ecosystem. There are one or two leafy *canopy* layers at the top, an *understory* of shrubs and smaller plants below tha canopy, and a layer of low-growing ground plants on the forest floor. The soil in forests is very rich in nutrients, due to the abundance of *leaf-litter*, and forests support a very high level of biodiversity. Animals found in deciduous forests include bears, deer, bobcats, raccoons, squirrels, as well as many birds and insects. One special kind of forest, the tropical rain forest, has the greatest diversity of species of all biomes – perhaps as many as all other terrestrial biomes combined.

Ponds and Lakes: Ponds and lakes are enclosed bodies of freshwater formed where water has collected in basins on the surface of the earth. Ponds and lakes can be natural or man-made. Unlike the ocean, freshwater in ponds and lakes has very little salt in it.

Ponds are smaller than lakes and usually are temporary. Ponds may fill in or dry up within a few seasons or years. Lakes may exist for hundreds of years or more.

Animals found in ponds and lakes include fish, snails, clams, insects, crustaceans, frogs, salamanders and many microscopic organisms. Other animals that find food in ponds and lakes include turtles, snakes, ducks, and muskrats.

Streams and Rivers: Streams and rivers are channels through which water flows continuously in one direction beginning in land from springs (or even lakes) and emptying into the ocean. Rivers are created when many small streams flow together to form a larger one. Animals that live in streams are adapted to flowing water. Some, like fish, are very good swimmers, and are streamlined to handle fast-flowing water. Others, like some insects and mussels, are good clingers that hold onto submerged rocks, wood, or vegetation to avoid being swept downstream.

Ocean: Oceans are huge saltwater areas between land masses that cover almost three-quarters of the earth's surface. The term for a saltwater habitat is "marine". Marine habitats include the inter-tidal zones, which are dry when the tide is low; deep water zones, which can be over 4000 meters (13000 feet) deep; the bottom or *benthic* zones; the coral reefs, which exist in shallower coastal waters; and estuaries, which have freshwater flowing into them and mixing with the ocean saltwater.

Although oceans contain saltwater, it is the evaporation of ocean water that provides most of the rain water that falls on land, and flows into freshwater streams, rivers, ponds, and lakes.

Appendix C

Knowledge Hierarchy for Ecological Science

Level 1: Minimal statement of very few characteristics of a biome or an organism. There are no ecological concepts or definitions. Statement may consist of no information beyond the student's name as identifying information.

a) 1-4 organisms correctly classified to a biome; OR
b) 1-2 factual characteristics about either one of the biomes, but no definition of a biome; OR
c) 1-9 organisms correctly identified, but not classified into any biome; OR
d) Student's name but no information; less than a-c.

Level 2: Students identify characteristics of one or more biomes, or they present several organisms correctly classified to a biome. There are no full definitions of biomes, accompanied classifications of organisms, or organism's adaptations to the biome. The information is minimal, factual, and may appear as a list. Information is largely accurate.

a) 5-up correctly classified organisms; OR
b) 3-6 characteristics, that are not definitional presented for the two biomes combine; OR
c) Limited biome definition [this includes a sentence and thought referring to the land mass or water system and its defining characteristics which are: desert = dry, grasslands = grass, forest = trees, pond =small water, river = channel of flowing water, ocean = large body of saltwater] additional information about the biome, but no added information about organism; OR
d) Extensive biome definition AND 1-2 correctly classified organisms; OR
e) Weak definition of biome AND 3-9 organisms correctly classified to biomes; OR
f) 2 Weakly stated concept AND possibly 1 correctly classified organism, or 1 or more non-classified organism.

Level 3: Students present one or more ecological concept with minimal supporting information and correct classifications of organisms to biomes. A higher-level principle that may entail multiple concepts, or may be presented with no rationale or supporting information about biomes or organisms. Also included, may be a well-formed, fully elaborated definition of both biomes accompanied by a substantial number of organisms accurately classified into the biomes.

a) 3 weakly stated ecological concept AND 2-10 organisms correctly classified to biomes but no relation to concept; OR
b) 2-4 concepts briefly stated in a disorganized, incoherent structure or list with no support and biomes are not identified or described; OR
c) Extensive biome definition; AND 3-or more correctly classified organisms; OR

d) 1 Clearly stated principle linking 2 or more concepts but no supporting information.

Level 4: Students display conceptual understanding of organisms and their survival mechanisms in one or more biomes. This is represented by specific organisms and their physical characteristics, and behavioral patterns that enable them to exhibit the concept as a part of their survival. They may include higher-level principles, such as food chains or interactions among ecological concepts, with very limited supporting information.

a) 2-4 coherently stated ecological concepts with minimal supporting information linking the organism information to the biome. [Coherent statement of concepts contains references to specific organisms and an aspect of the environment or other organisms it is interacting with] OR
b) 1 coherent concept with supporting information; AND 4-10 correct classifications of organisms to their biome; OR
c) 1-2 higher level principle or food chain (linking multiple ecological concepts) with vague and limited supporting information about the organisms; OR
d) Several ecological concepts, or a food web, with information based predominantly on pictures rather than text).

Level 5: Students show command of ecological concepts, and relationships among different organisms and various biomes. They describe organisms, their structural characteristics and their behaviors. The interaction of an organism to the environment is central to the statement.

a) 2-4 ecological concepts with specific, supporting information linking the organism mentioned to its biome; may also have 2-3 relevant facts about one or both biomes; OR
b) 1-3 ecological concepts with specific, extensive coherent supporting information about these concepts and the adaptations of a few (1-3) organisms to the biome; OR
c) Weak or partially incorrectly stated food chain, 1 clearly higher-order principle, with additional concepts and 6-10 classifications.

Level 6: Students describe complex relationships among multiple organisms and their habitats. These may appear as food chains in one or two biomes or as energy exchange in the living environment. Students support the principles with examples from diverse organisms. High -level principles that depict interdependencies among organisms in specific habitats are emphasized.

a) Food chain or food web, which refer to one biome, or both biomes separately or both biomes simultaneously or energy chain; AND correct classifications of 6-20 organisms to biomes; OR
b) Food chain or food web AND detailed, accurate account of physical characteristics or adaptive behavioral patterns of a few organisms; OR
c) High-level principle that shows relationship of two or more ecological concepts (e.g., competition and reproduction). Supporting evidence about the organism and

its relationship to another organism and/or the biomes descriptions are substantial and explicit.

Notes:
1. Stating a concept refers to a clear reference to one of the ecological concepts describing an organism's interaction with its environment.
Concepts consist of: *feeding, locomotion, competition, predation, reproduction, respiration, communication, defense, and adaptation to environment.*

2. Responses that contain more information than required at the concurrent level (2) but insufficient information for higher level (3), are placed at the lower level (2).

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