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Jamie N. Mikeska

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Christina V. Schwarz

Major Professor's Signature

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TOWARDS A MORE COMPLEX VIEW OF GENRE: THE IMPORTANCE OF PRIOR KNOWLEDGE AND THE NATURE OF THE SCIENCE CONTENT FOR UNDERSTANDING ELEMENTARY STUDENTS' COMPREHENSION OF INFORMATIONAL AND DATA SCIENCE TEXTS

By

Jamie N. Mikeska

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ABSTRACT

TOWARD A MORE COMPLEX VIEW OF GENRE: THE IMPORTANCE OF PRIOR KNOWLEDGE AND THE NATURE OF THE SCIENCE CONTENT FOR UNDERSTANDING ELEMENTARY STUDENTS' COMPREHENSION OF INFORMATIONAL AND DATA SCIENCE TEXTS

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In the early elementary grades, teachers use informational trade books and opportunities for students to interact with data to build students' understanding of science concepts. Teaching students how to read and comprehend these informational and data texts will help them learn scientific concepts and develop a better understanding of their world. However, to do so, we need research that describes what students do with these texts, particularly the strategies they employ and the resources they draw upon, and how their strategy use relates to their comprehension and prior knowledge. This knowledge is crucial to developing instructional approaches that directly impact students' facility with these specific texts.

This study speaks to this issue by investigating how third grade students interact with informational and data science texts. Specifically, I investigated the various strategies third grade students use when reading text similar to that found in informational science trade books and scientific data, focusing on the particular types and frequency of inferences they generated while doing so. In addition, I examined how differences in text type, topic, and students' prior knowledge are related to students' strategy use and their text comprehension. This research provides empirical evidence to show how students read and comprehend subject-specific texts and serves as a beginning step to determine how to best support students in understanding these texts.

A sample of 84 third grade students reading on or above grade level read four informational and data texts across two science domains (sound and plants). The informational texts focused on providing information about scientific phenomenon, specifically how sound is made and how plants grow, while the data texts presented scientific data related to the same topics and phenomenon. The study used think-aloud protocol methodology to capture the students' thinking as they read the texts. I conducted knowledge assessments to determine students' background knowledge related to sound and plants and asked students comprehension questions after they read each text.

Findings show that students used particular strategies, mainly inferences and paraphrases, to comprehend these texts and text genre, topic, and students' prior knowledge influenced their text interactions. These findings suggest that we need to move beyond thinking about text genre as simply the structural features of the texts and consider a broader definition of text genre to understand how students interact with and comprehend science texts. In particular, findings suggest that we need to more thoroughly consider the importance of students' prior knowledge and the nature of the science content that is represented in the texts to understand the strategies students employ during reading and their comprehension of these science texts.

DEDICATION

I dedicate this dissertation to my family.

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First and foremost, this dissertation would not have been possible without the principals and teachers who invited me into their classrooms and provided me with space and time to work with their students. Most importantly, I am grateful for every student who let me listen as they read and made sense of these science texts.

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During my graduate studies, I feel lucky to have been part of the science education community at Michigan State University. It is here that I met and worked with a number of graduate students and post-docs who helped shaped my thinking and scholarship. Jeff Rozelle was always willing to listen and respond to my ideas and never hesitated to argue with me at a moment's notice. Jodie Galosy showed me the "ropes" and taught me what it means to do research in the complexity of teaching. Finally, Patricia Bills and Dawnmarie Enzo graciously volunteered their time to cross code data and I appreciate every minute they spent thinking about my work.

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Problem Statement

Stop and think for a moment about the various texts you read today. Maybe you started by reading the label on the side of your cereal box to determine the nutritional components of your first meal of the day. While eating that bowl of cereal, you might have skimmed the local newspaper to learn about the latest developments in the world and your local community. During your morning commute, you likely read many street signs that helped you navigate your way to work as well as other signs advertising the latest products you should buy or local events you should attend. At work, you probably read emails from colleagues as well as various reports or documents related to your current project. Maybe you went to the gym after work and read a magazine or book while riding the exercise bike, went out to dinner and perused the menu to find the best dish, and finished the day by lying in bed with your favorite novel or magazine. What do these situations have in common? For the most part, you are reading different types of nonfiction texts – texts whose primary purpose is to provide facts representing real events, people, or information.

Nonfiction texts are a constant in our lives; we read and use them daily to help us complete tasks and to navigate and learn about the world around us (M. C. Smith, 2000; Williams, 2009). One particular type -- informational texts -- is especially valuable in developing our understanding of the natural and social world (Duke, 2000, 2004). Informational texts are a type of non-fiction text whose primary purpose is to "convey information about the natural and social world" (Duke & Bennett-Armistead, 2003, p. 16) while the purpose of other non-fiction texts may be to tell a "true story" about something that has happened in real life or to describe the procedures for how to do something. In addition, informational texts possess certain text features, such as technical vocabulary, graphical devices, and "talk about whole classes of things and in a timeless way" (Duke & Bennett-Armistead, 2003, p. 17) and can appear in various formats, such as magazines, websites, books, and pamphlets. Other types of non-fiction texts, such as biographies, usually are written using one particular format and are less likely to include the specific text features found in informational texts.

Researchers have documented the critical importance of fostering students' abilities to comprehend informational texts (Cote, Goldman, & Saul, 1998; Reutzel, Smith, & Fawson, 2005; Smolkin & Donovan, 2001), especially in light of findings that show students and adults alike have much difficulty understanding this text genre, the minimal attention given to these texts in instruction, and how important it is for students to develop informational literacy to function successfully in society (Caverly, Mandeville, & Nicholson, 1995; Duke, 2000; Duke, Bennett-Armistead, & Roberts, 2003; Gambrell, 2005; Moss, 2004; Spires & Donley, 1998). In the last decade, researchers have examined how informational texts can be used to build students' background knowledge, develop comprehension skills, positively affect content-area learning, and increase engagement and motivation (Cervetti, Pearson, Barber, Hiebert, & Bravo, 2007; Guthrie, Alao, & Rinehart, 1997; Guthrie, Anderson, Alao, & Rinehart, 1999; Guthrie, Wigfield, Barbosa, et al., 2004; Magnusson & Palincsar, 2004; McNamara & Kintsch, 1996; Romance & Vitale, 1992; Soalt, 2005).

The question of how best to support students' informational text reading and comprehension is important considering how ubiquitous this text genre is in students' lives and becomes even more important as students progress through school. One place where teachers can, and often do, use informational texts is in content-area instruction, that is, when they are teaching the academic subjects of mathematics, history, science and the like. However, research has fallen short in examining the nature of informational texts in content-area instruction and determining how to support students in learning from these content-area texts.

The challenge of helping students comprehend informational texts is particularly troublesome in the area of science. Much research has been conducted to document students' difficulty with comprehending information in science textbooks (Best, Rowe, Ozuru, & McNamara, 2005; Chambliss & Calfee, 1989; Glynn, Britton, Semrud-Clikeman, & Muth, 1989; Graesser, Leon, & Otero, 2002), the primary informational texts used in middle and high school science classrooms. However, less research has been conducted to examine the strategies students use to comprehend texts that are important to developing students' scientific literacy in the early elementary (kindergarten to third) grades.

Instead of textbooks, in the early elementary grades two different texts can be used to develop young students' conceptual understanding. Teachers can use informational trade books, which are texts that present information about single concepts in a more engaging format than traditional textbooks (Ford, 2006; Moss, 1991; Rice, 2002), as well as provide opportunities for students to interact with data to build their understanding of science concepts. This second kind of opportunity involves something I call a "data text": a text that provides observations of scientific phenomena. For example, in a science unit on the moon's phases, students might make daily observations of the moon and record information about the moon's shape and position in the sky. These observations, which could be expressed using words and/or pictures, would constitute the data text. It is important to note that a data text presents observations that can be used as evidence for students to identify patterns and build explanations, but does not explicitly express these patterns and explanations. These two text types – informational texts and data texts – are the ones elementary teachers are most likely to use during science instruction.

It is important to develop young students' abilities to comprehend these subject-specific science texts for two main reasons. First, these texts are the main vehicles for developing elementary students' scientific literacy. Students must be able to make sense out of science informational texts and scientific data in order to learn scientific concepts and develop a better understanding of their world (American Association for the Advancement of Science, 1993; National Research Council, 1996). Secondly, teaching students how to read and comprehend these texts can positively impact students' engagement and motivation to learn in this content area (e.g., Guthrie, Wigfield, & VonSecker, 2000; Romance & Vitale, 2001). If students struggle understanding scientific concepts at an early age, they might show decreased motivation and interest in learning science, which could have far reaching implications.

It is especially important that we attend to this issue of developing students' abilities to comprehend science texts due to the lack of attention focused on science instruction in the elementary grades. For the last decade, teachers have been immersed in the current political environment of mandates from the No Child Left Behind Act (U.S. Department of Education, 2001). Specifically, elementary schools are judged based on their state assessments scores in language arts and mathematics. The push for accountability in these areas has resulted in a more restricted curriculum in elementary classrooms. Researchers have found that teachers' decisions about what to teach is heavily influenced by such mandates; one consequence is that language arts and mathematics instruction has literally taken over the elementary school curriculum (King & Zucker, 2005; McNeil, 2000; M. Smith, 1991; Wright, 2002). This makes findings from this research study even more important; if elementary teachers are teaching science, it is likely that they are doing so in the context of helping students learn to read well for accountability purposes. We need to know how to help students comprehend informational and data texts to bolster their understanding of scientific concepts as well as their reading abilities.

As we encourage teachers to use such texts, we need research that describes what students do with these texts, particularly the strategies they employ and the resources they draw upon, and how their strategy use relates to their comprehension. This knowledge is crucial to developing instructional approaches that directly impact students' facility with these specific genres. This study speaks to the issue of how to b by investigating the strategies third grade students use to comprehend two types of science-related texts: informational texts (from trade books) and data texts. In particular, I investigate the types of inferences students generate to comprehend these texts.

Using Inference Generation as a Framework for Students' Strategy Use

Cognitive strategy instruction has been touted as a promising approach to help students construct meaning as they read and write a variety of texts (Conley, 2008; Pressley & Hilden, 2006; Pressley, Johnson, Symons, McGoldrick, & Kurita, 1989).

This instructional approach teaches students to use various strategies -- making predictions, connecting to prior knowledge, synthesizing ideas, generating inferences – as they interact with different texts. In this instructional approach, teachers model how to use the strategy, provide multiple opportunities for students to use the strategy with coaching, and then have students practice using the strategy while reading independently.

There have been calls for strategy instruction to be infused across the curriculum, specifically that "strategies should be practiced and mastered as part of ongoing reading, mathematics, and other content-related instruction" (Pearson, 1994, p. 25); however, these calls do not specify when and how strategies should be used within these other content areas. To date, little research has been conducted to examine how different cognitive strategies operate in various content areas (Cervetti, et al., 2007). For this reason, I decided to focus my investigation on how students engage in one particular cognitive strategy -- generating inferences -- while reading different science texts and how the inferences they generate relate to both their prior knowledge and comprehension. I selected the cognitive strategy of generating inferences as the focus of my investigation because, as I will discuss in the next chapter, this strategy is integral to students' text comprehension and their understanding of scientific concepts. That is, it is important for students to generate inferences in order to successfully comprehend informational and data science texts. This study is an attempt to address a gap in the research literature related to how cognitive strategies operate in the content areas.

Purpose and Research Questions

The purpose of this study is to describe and explain how third grade students interact with two different types of texts central to the science discipline – informational texts and data texts. Specifically, I investigated the various strategies third grade students use when reading text similar to that found in informational science trade books and scientific data, focusing on the particular types and frequency of inferences they generate while doing so. In addition, I examined how differences in text type, topic, and prior knowledge are related to students' strategy use and text comprehension. This research provides empirical evidence to show how students read and comprehend subject-specific texts and serves as a beginning step to determining how we can best support students in understanding these texts.

This research study addresses the following questions:

1. What strategies do third grade students use when reading two different types of science texts – informational texts and data texts – across two science topics (sound and plants)? Specifically, what types of inferences do they generate when reading informational science trade books and scientific data on these topics and what resources do they draw upon to generate these kinds of inferences?
2. How does text type (e.g., informational versus data) and topic (sound versus plants) relate to students' strategy use, particularly their inference generation? That is, do students use strategies with differing frequency when reading informational science texts and scientific data across these topics?
3. What is the relationship between students' prior knowledge, their strategy use, and their comprehension of text ideas? In particular, how does students' inference generation relate to their prior knowledge and comprehension?

Study's Contribution

Scientists use reading and writing as interactive-constructivist processes (Yore, 2004). The myriad of tasks that scientists engage in on a daily basis show that "language is a means to doing science and to constructing science understandings…to communicate about inquiries, procedures, and science understandings…" (Yore, Bisanz, & Hand, 2003, p. 691). In this sense, "language is implicated in the understanding, access to, and teaching of science" (Saul, 2004, p. 4).

In their work, scientists rely on and apply a variety of strategies to comprehend texts. In particular, while reading informational texts and scientific data, scientists generate inferences in order to construct a deep understanding of scientific concepts (Chi, 2000; Holland, Holyoak, Nisbett, & Thagard, 1986; Otero, Leon, & Graesser, 2002). Researchers have found that the generation of inferences is vitally important to developing a coherent situation model to comprehend texts (Kintsch, 1988; Kintsch & van Dijk, 1978; Lorch & van den Broek, 1997). This study contributes to our understanding of the strategies students use to comprehend two different types of texts integral to science – informational texts and data texts. In addition, findings reveal how students' prior knowledge and strategy use relates to their comprehension (e.g., what strategies are most useful for promoting students' understanding of scientific concepts). Findings can help teachers design instruction that support students in being "more strategic both when reading and when engaging in [scientific] inquiry" (Cervetti, Pearson, Bravo, & Barber, 2006, p. 233). This study is one response to calls for research to examine the use of a wider range of text genres in elementary science and the genre-specific nature of reading comprehension with a greater variety of texts (Block & Parris, 2008; Cervetti, Bravo, Hiebert, Pearson, & Jaynes, 2009; Duke & Martin, 2008).

Overview

In chapter two, I review the literature and research base that relates to this research. This study is based on a cognitive model for processing text that highlights how readers construct a mental representation using the explicit text statements and their own background knowledge. Essential to this text comprehension process is the generation of inferences. In this chapter, I begin by detailing what it means to make inferences and presenting a theoretical model that explains the process of text comprehension and highlights the importance of inferences in this process. Then, I examine research that has been conducted regarding the role of inference generation in comprehending narrative, informational, and data texts and provide a rationale for the focus on inference generation in this study. Next, I discuss factors that may affect students' abilities to comprehend text and generate inferences and explain the rationale for using think aloud methodology to capture students' cognitive processing as they read these science texts. I conclude this chapter by describing a conceptual model for the relationship between individual and text characteristics, students' strategy use, and comprehension and explain my research hypotheses.

In chapter three, I delineate the methodology, research design, instruments, and data analysis used in this study. First, I describe the selection and characteristics of the study's participants. I then provide details about the main parts of the research design, including how I collected data as well as the purpose and use of the research instruments.

Finally, I explain how I analyzed the data and examined the relationship between prior knowledge, students' strategy use, and comprehension.

In chapter four, I argue that students used particular patterns of strategies (inferences and paraphrases) when reading these different texts and that these patterns do not split neatly across text type or topic divisions. These findings suggest that thinking about text differences in terms of the structural features of genre misses important distinctions. To support this argument, I use descriptive statistics and relevant examples to describe the individual strategies students used to comprehend these texts by text type and topic, reporting statistically significant differences for types of strategies used across the four texts. This section addresses the study's first two research questions.

In chapter five, I argue that prior knowledge is critically important for generating inferences and supporting students' comprehension of these science texts, while students' strategy use appears to have less influence on students' comprehension. Specifically, in the first part of this chapter, I detail patterns in students' responses in the sound and plants prior knowledge interviews; this analysis reveals potential sources for students' inference generation. Then, I examine to what extent students rely upon their prior knowledge to generate inferences. In the chapter's second half, I examine students' typical responses to the comprehension questions to showcase their understanding of text ideas. I also explore how students' comprehension is related to their strategy use and to their prior knowledge. This chapter provides answers to the study's third research question.

In chapter six, I provide a detailed description of the strategies one student used to comprehend each text. I describe the ways in which he relied upon his prior knowledge to generate inferences as well as how his prior knowledge and strategy use were related to his text comprehension. The purpose of this chapter is to illuminate the relationships between prior knowledge, text interactions, and comprehension identified in chapters four and five.

I discuss the interpretation, significance, and implications of the major research findings in chapter seven. Here I argue that there is a complex set of relationships between individual and text characteristics, students' strategy use, and comprehension. Students' strategy use, particularly their inference generation, is related to some extent to text type and topic; however, students' prior knowledge and comprehension are also implicated in these relationships. There is evidence that students do draw upon their prior knowledge to comprehend these texts; however, the relationship between students' strategy use and comprehension is only robust with one inference type – explanations – and for one text. These findings suggest that researchers and teachers need to attend more closely to students' prior knowledge and the nature of the science content in considering how to best support students in learning from these subject-specific texts.

Chapter 2: Literature Review

In this chapter, I provide a rationale for the various features of this study. I begin by explaining what it means to make inferences; discuss the model of text processing and inference generation used in this study; explain how students generate inferences when comprehending narrative, informational, and science data texts; and explain why I applied an inference generation framework to analyze students' strategy use. Then, I provide reasons for the attention I give to potential factors related to students' text comprehension and/or inference generation: prior knowledge, word decoding ability, text genre, text features, and reading purpose. Next, I discuss why I used think aloud methodology as a window into students' cognitive text processing. I conclude this chapter by: 1) presenting a conceptual model that details theorized relationships between individual and text characteristics, students' strategy use, and comprehension and 2) explaining hypotheses related to students' strategy use with science informational and data texts.

Inferencing as a Cognitive Process to Construct Meaning

Inferencing is considered to be a higher level cognitive skill (Cain, Oakhill, & Bryant, 2004) because one must integrate multiple pieces of information to successfully engage in this process (Richards & Anderson, 2003). As Keen and Zimmerman (1997) describe:

> To infer as we read is to go beyond literal interpretation...We create an original meaning, a meaning born at the intersection of our background knowledge (schema), the words printed on the page, and our mind's capacity to merge that combination into something uniquely ours...As we read further, that meaning is revised, enriched, sometimes abandoned, based on what we continue to read (p. 149)

Inferences are often referred to as "evidence-based guesses" that require one to "read between the lines" to draw conclusions (ESA Regions 6 & 7, p. 4). One of the defining characteristics of inference-making is the ability to fill in information or draw conclusions from information or evidence provided (Cain & Oakhill, 1999). The key to the process of making inferences is linking ideas to understand an implied message. In doing so, one must call upon background knowledge about a topic or situation to understand an implied message or idea (Nokes, 2008). Background knowledge is an essential component for constructing valid and logical inferences (Hirsch, 2003). When making inferences, one must establish relationships between various pieces of information; the primary goal is to create a plausible and coherent model of a situation or text. This process requires one to supply missing knowledge in order to construct "a meaning not necessarily explicit in the text, but which derives or flows from it" (Keene & Zimmerman, 1997, p. 151).

Inferences are different from observations. When one makes an inference, one interprets empirical evidence and arrives at a conclusion or explanation through reasoning (Nokes, 2008). Observations do not require one to engage in reasoning to arrive at a conclusion; instead, observations are defined as information that a person can discern by using his/her senses. For example, one can observe that certain objects sink or float in water. However, one must infer that density accounts for the different behavior of objects in water. Inferences can be based on evidence gleaned from observations. Scientific models and theories are examples of inferences and are based on evidence in the natural world. For example, Darwin's theory of evolution is based on evidence from fossil records, chemical and anatomical similarities between living things, geographic distribution of similar species, and genetic changes over generations (http://anthro.palomar.edu/evolve/evolve_3.htm). I now turn to a discussion of the model of text processing and inference generation I used in this study, which sets the stage for understanding how reading and science researchers have examined students' text comprehension.

A Model of Text Processing and Inference Generation

One key assumption of this study is that inference generation is important for developing students' understanding of texts. In this study, texts are defined as any written discourse used for the purpose of communication about ideas, concepts, events, or opinions. Thus, the informational and data texts are both examples, and ones that are prominent and important in science instruction. In this section, I discuss how one constructs meaning from text and identify when and where potential inferences are generated in the process.

This study is based on a cognitive model for processing text. In this model, readers construct a mental representation of the text using information from two key sources: explicit text statements and the reader's general background knowledge (Kintsch, 1988; Kintsch & van Dijk, 1978; McKoon & Ratcliff, 1992; D. A. Norman, 1983; van Dijk & Kintsch, 1983). I chose this model of text comprehension because, as I will discuss below, it prominently featured the role of background knowledge as a critical component to text comprehension. Since this study focuses on students' strategy use and comprehension of subject-specific texts, and these texts are closely linked to particular science topics, it seemed important to make sure the model I selected brought to the forefront the role of prior knowledge in this process; Kintsch's construction-integration model does. It is the interaction between the reader and the text that is vitally important for text processing, although the reader's activity, or purpose, when interacting with the text, along with the sociocultural context in which comprehension occurs, also function prominently in the construction of meaning (Snow & Sweet, 2003).

As one reads the explicit statements in a text, a variety of mental operations occur in order to process these statements and encode them into memory (Kintsch, 1988; Kintsch & van Dijk, 1978; Lorch & van den Broek, 1997). These mental operations do not necessarily happen in a sequential manner, but likely occur in a parallel and cyclical fashion (Graesser & Kreuz, 1993; van Dijk & Kintsch, 1983), although for ease of discussion they will be presented in a stepwise manner.

In Kintsch's construction-integration model, readers begin by forming a linguistic representation of the text, which means that they decode the explicitly written words, or surface code. Once the written text is decoded, the reader constructs a coherent text base, by interpreting the written text as a set of propositions, which are individual ideas or concepts that are used to identify the meaning of individual sentences. These propositions form the structure which enables a more complex understanding.

In order to create a coherent text base, a reader relies on his or her background knowledge (Vellutino, 2003). The written text activates the reader's background knowledge and the reader uses this knowledge as a filter to construct an accurate and reasonable interpretation of the propositions. Schemata, or mental structures that store background knowledge in long-term memory, are integrated stores of knowledge that help one make sense out of the world and are used in this process (R. C. Anderson & Pearson, 1984). For example, a text about taking a trip may activate one's schemata for making plane reservations, packing a suitcase, and scheduling a sightseeing itinerary. Once these individual propositions, or ideas, are formed and activate the reader's background knowledge, one then constructs links across them to create a coherent situation model. The text base is constructed by interpreting the text as a set of propositions and the situation model is created by linking these propositions into a meaningful whole. The notion of local and global coherence is an integral component to this process.

Coherence refers to the idea that the propositions, or ideas, in the text are in harmony with one another as well as the world knowledge one brings to the text and can be established at two levels – either locally or globally (Graesser, McNamara, & Louwerse, 2003). The reader's text representation is considered to be coherent when the propositions fit together in an organized and structured way, which fosters understanding. Local coherence is established between short sequences of propositions, usually those spanning no more than two to three sentences, while global coherence refers to the organization of chunks of information across larger passages of text (Graesser, Singer, & Trabasso, 1994). When a reader faces a break in coherence during reading, he or she may attempt to fill these conceptual or structural gaps by generating inferences to make connections between the propositions in working memory and those held in short-term memory, which come from the text recently read, or long-term memory, which originate from a person's background knowledge. Generating inferences is an essential component for establishing coherence successfully at both local and global levels. In order to comprehend the text, readers must understand the relationship between ideas and concepts, otherwise understanding of the text falters and comprehension is unsuccessful.

The creation of a situation model is afforded through the linking of these propositions, or ideas, into a meaningful whole. A situation model includes the meaning of the text and represents an "integrated structure of episodic information" (van Dijk & Kintsch, 1983, p. 344). The construction of these two levels of representation -- a text base and situation model -- is cyclical in nature (Kintsch, 1988); that is, one continues to read additional text, interpret the text as a set of propositions, generate inferences to link these propositions into a meaningful whole, and integrate explicit and implicit ideas and concepts from the text and one's background knowledge in continuous cycles during reading to arrive at an individualized interpretation of the text. In this sense, inference generation includes elements of both bottom-up and top-down processing. The construction of propositions and coherent links between these idea units is similar to a bottom-up processing approach, while the activation of relevant background knowledge and interpretation of ideas using one's schema is reminiscent of a more top-down strategy.

These ideas detailing how one constructs his or her text understanding are buttressed by the literature on mental models, which focuses on reasoning and decision-making processes. In particular, mental model theory proposes that people create mental models to understand and explain empirical phenomena and situations as well as reason about related situations (Gentner & Stevens, 1983; Johnson-Laird, 1983). These mental models are conceptualizations of physical objects, systems, events, or situations, are based on a person's beliefs and observations, and have predictive power (D. A. Norman, 1983). To form these mental models, people rely on their previous experiences and prior knowledge and then use these mental models to form the basis for understanding their interactions in the world. As D. A. Norman (1983) explains:

> ...people's views of the world, of themselves, of their own capabilities, and of the tasks they are asked to perform, or topics they are asked to learn, depend heavily on the conceptualizations that they bring to the task. In interacting with the environment, with others, and with the artifacts of technology, people form internal, mental models of themselves and of the things with which they are interacting. These models provide predictive and explanatory power for understanding the interaction (p. 7).

When reasoning about phenomena, these mental models act as resources that support the generation of inferences, particularly the prediction of events and the formulation of explanations (T. Anderson, Howe, & Tolmie, 1983; Johnson-Laird, 1980). Johnson-Laird (1983) makes the distinction between explicit and implicit inferences. Explicit inferences are ones that require a concerted effort while implicit inferences are made seemingly automatically. The inferences that students generate, regardless of whether or not they require conscious or effortless processing, are directly connected to the mental models they have constructed of phenomena or situations. Thus, these mental models are used extensively during students' text comprehension to construct a coherent mental representation.

Inference Generation as a Key Component of Text Processing

Since inference generation is an essential component of students' text processing and, as will be discussed below, supports students' comprehension, I analyzed students' strategy use through the lens of inference generation; that is, I began by considering what types of inferences students made while reading these texts, but also recognized other strategies they employed. Researchers have examined the strategies and types of inferences students make when reading different types of narrative and informational texts and when working with science data. The research focused on narrative and informational texts has been conducted almost exclusively by reading researchers while science education researchers have investigated the latter topic. The purpose of this section is to review key findings from both areas with an eye towards learning about the specific types of inferences students generate to comprehend these different texts. This literature informed how I coded the strategies students used.

The role of inference generation in comprehending narrative and informational texts. The ability to make inferences is integral to text comprehension (R. C. Anderson & Pearson, 1984; Phillips, 1988; Pressley & Afflerbach, 1995). During reading, one must focus on integrating information across words, sentences, and ideas to create a mental model of the text. Since inferences are essential for integrating information, researchers have examined how readers generate inferences with different texts in various contexts.

Reading researchers have examined what types and when inferences are generated during the comprehension of written texts (Allen, 1985; Cain & Oakhill, 1999; Cain, Oakhill, Barnes, & Bryant, 2001; Caldwell & Leslie, 2006; Carr, 1991; Dewitz, Carr, & Patberg, 1987; Durgunoglu & Jehng, 1991; Graesser & Bertus, 1998; Hansen, 1981; Linderholm, 2002; Long, Golding, & Graesser, 1992; McKoon & Ratcliff, 1986, 1992; Phillips, 1988; Suh & Trabasso, 1993; Yuill & Oakhill, 1988). Research methods used in these studies span a wide range, including cued recall, sentence verification, sentence reading times, on-line question answering methodology, recognition tests, lexical decision tests, naming tasks, the modified Stroop task, and think-aloud methodology (Keenan, Potts, Golding, & Jennings, 1990; Pressley & Afflerbach, 1995). In addition, researchers have relied upon a variety of texts, including single sentence texts, short narrative stories, researcher-generated texts, and, to a lesser extent, informational texts to examine inference generation. A result of this wide variance in methodology and materials used to investigate the process of inference generation has been an abundance of findings related to the different types of inferences readers can generate during text comprehension. Although these findings are sometimes contradictory in terms of what type and when certain inferences are generated during comprehension, there are some reasonably reliable conclusions that one can draw.

Researchers have identified different types of inferences that readers must make to construct a coherent model of the text's meaning. Although researchers use different terms to refer to similar kinds of inferences, the purpose for or characteristics of the inference are quite similar. The most prevalent method for classifying inferences focus on how the content of the inference relates to the explicit text (Graesser, et al., 1994; Pearson & Johnson, 1978). Graesser et al. (1994) refer to these different types of inferences as text-connecting and extratextual inferences, both types of "bridging" inferences discussed earlier. Text-connecting inferences link together two ideas in the text, while extratextual inferences require the use of one's prior knowledge. In a similar vein, Oakhill and Cain (1999) defined two types of inferences: text-connecting inferences and gap filling inferences. Text-connecting inferences require readers to integrate multiple pieces of information that have been explicitly stated in the text, while gap filling inferences involve readers in incorporating information outside of the text. Other terms, such as elaborative inferences and slot filling inferences, have been used to describe inferences which require readers to apply their background knowledge in order to supply missing details, akin to the extratextual and gap filling inferences described above.

Another classification method considers the content of the inference as well as the information one uses to generate the inference. Trabasso and Magliano (1996) designed a framework to analyze the different types of inferences that occur during text comprehension as well as the information sources and memory operations used to make these inferences. Predictions are future oriented inferences that require the reader to generate expectations about upcoming events or ideas in the text. On the other hand, explanations are backward oriented and provide answers to questions regarding why something occurs. Another type of inference, called associations, involves elaborations of information in the text; when readers make associations, they typically draw upon information from their background knowledge to fill in details in the situation model. Van de Broek et al. (1993) called these three major types of inferences forward, backward, and concurrent inferences. In addition, Trabasso and Magliano (1996) determined whether the inferences generated relied on the activation of new, relevant background knowledge; was maintained from the previous sentence or thoughts immediately preceding the current sentence; or was retrieved from prior thoughts or sentences earlier in the text.

It is important to note that the distinction between the text-connecting and extratextual inferences is related to the origin, or source, for the inferences. That is, the most important distinction lies in what students rely upon (either textual information or their background knowledge) to generate these inferences. However, Trabasso and Magliano's method more carefully considers the content of the inferences and their purpose in relationship to students' text comprehension -- either to explain, predict, or associate – along with the knowledge source students rely upon – either textual ideas or prior knowledge – to generate each inference.

One source of contention in this area of research relates to whether inferences are created online (during reading) or offline (after reading) and whether certain inferences are made in the absence of goal-directed purposes. Some researchers maintain that there are particular classes of inferences that tend to be made automatically, or "on-line," during the course of reading. For example, McKoon and Ratcliff (1982) propose that readers generate inferences automatically when they contribute to a coherent representation of the text or are based on easily available information in short- or long-term memory. Pressley and Afflerbach (1995) examined multiple studies and identified potential inferences readers consciously generate as they make sense of texts. Their review of the research literature regarding conscious processes during skilled reading revealed that readers generate many different types of inferences on-line to construct a coherent mental representation of the text. These inferences include inferring the referent of a pronoun; filling in deleted information; inferring the meanings of words; relating text information to prior knowledge; making inferences about the author, speakers, actors, or world depicted in a text; and drawing an implied conclusion (pp. 46-48).

However, other researchers argue that certain inferences seem to require more strategic and focused effort and are only made when the situation requires an inference to be drawn, particularly when readers are engaged in goal-directed reading tasks or when readers are asked about their understanding of the text after reading. For example, explanations can be considered to be either automatic or non-automatic inferences, depending on the circumstances surrounding their generation. Explanations can be created automatically online if they contribute to the coherent understanding of the text or they can be created offline (non-automatic) in response to comprehension questions or a different goal-directed task. That is, the different types of inferences described above (text-connecting, extratextual, explanations, predictions, associations) can be created during or after reading, depending on contextual factors that influence their generation.

Another consistent finding regards factors that influence students' ability to generate inferences. These factors include differences in background knowledge, reading proficiency, working memory capacity, text genre and organization, and reading purpose (Cain & Oakhill, 1999; Phillips, 1988). I will explore factors that influence students' inference generation and text comprehension in more depth later in this chapter.

The role of inference generation in interpreting science data. Much research that examines inference generation in science has been conducted in the context of investigations on scientific reasoning (Chi, De Leeuw, Chiu, & Lavancher, 1994; Chi, Glaser, & Rees, 1981; Eberbach & Crowley, 2009; Kuhn, Schauble, & Garcia-Mila, 1992; National Research Council, 2008; Roychoudhury, n.d.; Schauble, 1996). During science instruction, students may be presented with various opportunities for making inferences. For instance, students can make inferences when they use their background knowledge to interpret scientific data and observations (Driver, Guesne, & Tiberghien, 2002). The researchers state that "observations of events are influenced by the theoretical framework of the observer…the observations children make and their interpretations of them are also influenced by their ideas and expectations" (p. 3). Making sense of observations is dependent on being able to connect pieces of information together into a coherent picture.

When making sense of scientific data, one situation in which students generate inferences occurs when they engage in pattern finding using either data they have collected (firsthand) or been given (secondhand) to draw conclusions regarding the phenomena under study. To do so, they investigate the data for patterns and identify those patterns that are most plausible and supported by the data at hand. Patterns tend to be based on visible kinds of accessible evidence, such as noticing that sound is produced when an object moves or observing that a light source is needed to make shadows. These types of inferences are less dependent on background knowledge and more dependent on the actual data at hand – in a sense drawing upon text as the primary information source, much like the text-connecting inferences mentioned earlier.

Another way that students make inferences while making sense of scientific data occurs when they integrate data across successive trials in order to arrive at valid conclusions and propose explanations to justify the outcomes. For example, Schauble (1996) designed an instructional unit that focused on key concepts related to why objects sink and float; students had to draw inferences among multiple concepts to develop an understanding of variables that affect the carrying capacity of boats. For each experimental variable, the student could have identified the variable as either causal (inclusion inference), non-causal (exclusion inference), or impossible to decide (indeterminancy). These inclusion inferences occurred when students determined that a particular variable (e.g., size of the boat) caused a change in the outcome, based on their experimentation and tried to explain the reasoning for the finding. Exclusion inferences occurred when students showed that a particular variable did not cause a change in the outcome and, similar to inclusion inferences, provided reasoning for this finding. Both types of inferences, which allude to the reason why certain outcomes exist, are specific examples of explanations, one type of inference identified by Trabasso and Magliano's (1996) coding scheme.

Other studies also investigated how students generated inferences when coordinating patterns with evidence, but also examined the source for each inference. For example, Kuhn, Schauble, and Garcia-Mila (1992) found that students improved in their ability to construct interpretable experiments and draw inferences from the results. In this study, the researchers examined the extent to which the inferences students generated were based upon the evidence available to them from the data. This focus on the source, or origin, of students' inferences was also noted in the studies from the reading research community. In this case, the main source for inference generation was the actual data. In another study, Roychoudhury (n.d.) examined students' written reports to see whether they drew inferences from observations and, if so, what kinds of justifications they provided for the inferences. Findings revealed that students can improve in their ability to generate and justify inferences and consider anomalous data when doing so. In this study, we also see the focus on the source of students' inferences, In science, it is important that students coordinate the data patterns they identify with evidence, one of the hallmarks of scientific reasoning; this evidence can originate from the data or from a person's background knowledge and experiences.

Another situation in which students make inferences while reasoning about scientific data occurs when they develop scientific explanations to explain the data patterns and when they apply explanations to new contexts and situations. These inferences are more akin to the gap filling inferences mentioned earlier. Students must propose models or theories to explain why these patterns exist; for example, using the idea that light travels in a straight line to explain how shadows are made. They also must apply explanations when reasoning about novel situations; for example, using the concept of density to explain why ice cubes float.

Unlike pattern finding, developing scientific explanations involves relies upon visible evidence to describe invisible mechanisms and background knowledge is indispensable in this situation. Students can leverage their related experiences to consider possible explanations for the patterns in the data. However, sometimes students struggle to coordinate explanations and evidence and to use evidence to support conclusions successfully (Germann & Aram, 1996). This means that when generating inferences with data texts students might be more likely to make incorrect explanations, especially if they have limited prior knowledge about the topic. In summary, research has shown that in science students have opportunities to interpret experimental data and in doing so must detect relational patterns and construct explanations to account for patterns in the data; both processes involve drawing upon text ideas and prior knowledge to make inferences to establish key relationships.

Summary. As the research on inference generation has revealed, students generate different types of inferences as they read various texts. Students generate explanations to establish causal reasons for why certain things occur and these explanations are quite prominent and important when linking scientific theory with evidence. They also make predictions, or expectations about upcoming events or ideas, and associations, or elaborations of text ideas, to connect multiple pieces of information together. When making these different types of inferences, students can draw upon text ideas, as the text-connecting inferences do, or their background knowledge, like in the extratextual inferences, in order to construct a text base and situation model to understand the main ideas addressed. In addition, inferences can be generated both online and offline and can occur automatically or in response to goal-directed tasks.

Applying an Inference Generation Framework to Analyze Students' Strategy Use

In this study, I drew upon these findings about students' inference generation to analyze students' strategy use. I decided to apply an inference generation framework to analyze the strategies students used as they read the science informational and data texts. In particular, this framework examines both the types of inferences students generate (explanations, predictions, or associations) and the knowledge sources (activation of background knowledge, maintenance of a text idea, or retrieval of a text idea) they rely upon when doing so. I will describe this coding scheme in more detail in chapter three.

I used this framework to code students' strategy use for a variety of reasons. First, as Kintsch's construction-integration model of text processing shows, students must generate inferences to construct a coherent situation model in order to understand the text's main ideas. Secondly, the generation of inferences is a critical and necessary component to interpreting scientific data and connecting theory with evidence to understand the data. In this framework, I examined both the content of the inferences (i.e., what types of inferences students generated) and the source of each inference in order to develop a more detailed picture of how students engage in inference generation using subject-specific texts. In the coding scheme I also included additional strategies that students used when reading these texts; I used an iterative process to develop these additional codes and did so to capture the full extent of students' strategy use.

Factors that Influence Students' Text Comprehension and Inference Generation

The process of inference generation occurs in the context of comprehending text, which, in this study, is defined as written discourse used for the purpose of communicating about ideas, concepts, events, or opinions. In this section, I discuss several factors that research has shown influence children's ability to comprehend text and/or generate inferences and discuss how I account for or examine these factors in this study. Some factors are characteristics linked to individual students, such as prior knowledge and word decoding ability, while other factors are characteristics related to the actual texts or context for the reading task, such as text genre, text structure, and reading purpose.

Individual characteristics. There are characteristics that students bring to the task which influence their ability to successfully comprehend text and generate inferences, including students' prior knowledge and their ability to accurately decode the text.

The facilitative role of prior knowledge. The effects of prior knowledge on text comprehension have been studied extensively and findings show that prior knowledge has a facilitative effect on reading comprehension and inference generation (Carr, 1991; Kintsch, 1988; Pearson, Hansen, & Gordon, 1979; Phillips, 1988; Recht & Leslie, 1988; Schmidt & Patel, 1987; Wilson & Anderson, 1986; Yanowitz, 2001). For example, Phillips (1988) investigated the inference strategies of sixth graders while they read multiple narrative texts addressing either familiar or unfamiliar topics and found that high proficiency readers with high background knowledge use different strategies for inference making than low proficiency readers with low background knowledge. High proficiency readers with high background knowledge tend to shift focus when trying to resolve incomplete interpretations, confirm prior interpretation, and empathize with characters' experiences. In contrast, low proficiency readers with low background knowledge are more likely to restate text ideas, assume an incorrect interpretation, and transform subsequent text information to make it consistent with their interpretation. Phillips (1988) suggests that prior knowledge, in this case the familiarity of the text topic, prompts students to use different strategies to comprehend texts. In a related study, Afflerbach (1990) investigated how expert adult readers constructed main idea statements while reading texts about familiar and unfamiliar topics and found that the process of main idea construction is facilitated by high prior knowledge. Readers more frequently construct main idea statements automatically when reading familiar texts and draw on their prior knowledge about the topic to do so. Schema theory explains these findings in terms of assimilation (R. C. Anderson & Pearson, 1984). Readers who possess well-developed schema regarding a particular topic are better able to assimilate new information and knowledge about that topic into a coherent mental representation and, in turn, are better poised to generate inferences as they read a text.

Prior knowledge also has been shown to be an important factor related to students' science learning (Driver, 1989; Glasson, 1989; P. W. Hewson, 1982). Specifically, prior knowledge has been found to facilitate students' understanding of scientific phenomena, especially when students' current mental models closely match scientific theories about the phenomena (Chinn & Brewer, 1993; Schauble, 1990;

Schmidt, De Volder, De Grave, Moust, & Patel, 1989). Research has shown that students' prior conceptions infrequently match current scientific conceptions and that instruction taking into account students' prior knowledge can positively impact their learning (Chambers & Andre, 1997; M. G. Hewson & Hewson, 1983). It is hypothesized that prior knowledge provides a vehicle by which students can activate and apply new ideas.

Poor word recognition skills weakens inferential ability. Students' ability to decode words written in a text, sometimes referred to as "breaking the code," has been shown to influence their reading comprehension and their ability to draw inferences during reading. Allen's (1985) study of first to third graders' inferential reasoning performance when reading texts written by themselves, their peers, and adults found that students' word recognition accuracy significantly contributed to their inferential ability. In another study, Phillips' (1988) studied how sixth grade readers' use of inference strategies interacted with their reading proficiency (high or low) and their background knowledge associated with text content (familiar or unfamiliar). Findings provide empirical evidence that the inference strategies readers use is dependent on both proficiency and background knowledge. Stated simply, students who are more accurate decoders and are more familiar with text content are more likely to make correct inferences and understand the text better.

Just and Carpenter's (1992) capacity theory of comprehension helps to explain these findings. This theory is based on the idea that individuals only have a certain capacity in their working memory to process sentences and build mental representations. If a reader is struggling with decoding the written words, then the majority of his or her working memory capacity is focused on the task of processing the written symbols with little, if any, capacity left to devote to the process of integrating ideas and concepts. As a result, the reader produces a less accurate and more shallow representation of the text, which is evidenced by fewer inferences drawn and reduced comprehension (Budd, Whitney, & Turley, 1995). Likewise, with limited background knowledge about the topic in the text, readers will spend a majority of their working memory trying to understand the ideas instead of trying to assimilate the ideas into their current mental representation. This process of "starting from scratch" means that there is less integration of ideas and concepts, likely resulting in a more limited understanding.

In this study, I accounted for or examined these individual factors in various ways. When selecting the study's sample, I only chose third grade students who were reading at or above grade level. I excluded any students who were reading below grade level or who had any identified reading disabilities. My goal was to ensure that the students in this study could devote the majority of their working memory capacity to processing the text ideas and building a coherent mental representation, without being encumbered by struggles decoding the actual printed words. I chose third grade students, in particular, because this time is an important period in which students begin to transition from "learning to read" to "reading to learn." In order to more closely examine the relationship between prior knowledge, students' strategy use, and comprehension, I used interviews to document students' topic-specific prior knowledge about sound and plants prior to reading these texts. By doing this, I could investigate whether students with more prior knowledge about a particular topic were more likely to generate inferences as well as comprehend the texts better.

Text characteristics. In addition to individual characteristics, there are also text characteristics that have been shown to influence how students process text and generate inferences. Text genre, text structure, and reading purpose all play an important role in this process (Allen, 1985; Britton, Graesser, Glynn, Hamilton, & Penland, 1983; Britton & Gulgoz, 1991; Cain, et al., 2004).

Text genre as a defining feature. Many recent studies have examined the genre specific nature of students' strategy use and reading comprehension. In this work, the main distinction has been between narrative texts, whose purpose is to tell about a sequence of events, and informational texts, whose purpose is to provide information about the natural and social world. Some research has shown that readers tend to make more inferences while reading narrative texts than while reading informational texts (Graesser, 1981). Other researchers investigated how text genre influences the specific types of inferences students generate. For example, Narvaez, van den Broek, and Ruiz (1999) found that readers generated more explanations and predictions while reading narrative texts and more associations when reading informational texts. Zwann (1994) examined how students' expectations about text genre influenced their text comprehension and found that students differ in the processes they use to create text representations for literacy stories as compared to news stories. Taken as a whole, these studies suggest that text genre, or text type, is a feature that likely influences how students process and comprehend texts.

Text structure impact comprehension. Informational texts can vary in the extent to which the text is structured in terms of text organization and cohesion among ideas (Armbruster, Anderson, & Ostertag, 1987; McGee & Richgels, 1985). Research on text structure has found that such features can impact text comprehension in the following ways: 1) structured, well-organized informational texts enhance the quantity and/or quality of students' recall (McGee, 1982; Richgels, McGee, Lomax, & Sheard, 1987; Taylor & Samuels, 1983); 2) texts with simpler vocabulary, less challenging syntax, and a greater frequency of signals about idea importance required less cognitive capacity to process (Britton, Glynn, Meyer, & Penland, 1982); and 3) instruction and practice that helps students understand text structure enhances students' text comprehension (Armbruster, et al., 1987; Carrell, 1985, 1992; Piccolo, 1987; Taylor & Beach, 1984).

Reading purpose influences student-text interactions. The purpose for reading a text can be imposed by an outside influence, such as a teacher, researcher, or goals for an assignment, or can be determined by the reader. Typical reading purposes include reading for entertainment or reading to learn new information; both purposes can be directed for a goal specific task, such as reading a novel to prepare for a book club discussion or reading an informational text in order to teach another student about that topic. Studies have found that students may be motivated by particular reading purposes, which supports more engaged text processing (Guthrie, Wigfield, & Perencevich, 2004). In particular, Narvaez et al. (1999) used both narrative and expository texts to examine how reading purpose influences the types of inferences readers make and their reading comprehension. They found that the reading purpose, which was either for entertainment purposes or for study purposes, impacted the strategies students used while thinking aloud. When students had a study purpose, they were more likely to restate text ideas, recognize when they lacked background knowledge, and evaluate text content. Likewise, Linderholm and van den Broek (2002) found that students' text processing and recall of text ideas changed according to reading purpose. These findings suggest that differences in reading purpose can impact students' text interactions and comprehension.

When designing this study, I made specific decisions to account for the potential influence of these text characteristics. First, in the task directions I set the same reading purpose for students across all four texts. In particular, I explained to students that their goal-specific reading purpose was to "to read carefully so that after reading you will be able to tell a friend about…" either how a particular plant (pumpkin plant or oak tree) grows or how sound is made; the goal was matched to a study purpose. Second, I decided to include two text types important to the science discipline – informational texts and data texts – in order to examine how students' strategy use and comprehension is related to text genre. In addition, I selected texts with similar reading levels matched to the reading level of the students in this study. I also made sure that the sound and plants informational texts had similar text structures, meaning they were written using generalizing quality and timeless verb construction typical of these text types and presented science knowledge in terms of facts. Likewise, I created data texts that presented secondhand observations from another student's interaction with real-world phenomena; these data texts presented the student's observations in a chart format and the observations were written using a first-person perspective. I decided to exclude pictures and photographs from the texts because these graphical aids served as another possible variable that could influence students' text interactions. While there are many interesting and important reasons to study students' interactions with pictures and photographs, there are already many complicated aspects to make sense of in this context. I was concerned that the addition of one more factor that had the potential to influence how students interacted with these different texts would further complicate the research design. Lastly, I included two topics in my investigation – sound and plants -- in order to determine in what ways, if any, the content domain interacted with students' strategy use and comprehension.

Think Aloud Methodology as a Window into Students' Cognitive Text Processing

Think aloud methodology focuses on understanding an individual's thoughts and actions and involves a process of having a person verbally report his or her thought processes either during or after engaging in some type of task (Ericsson & Simon, 1984; Kucan & Beck, 1997; Pressley & Afflerbach, 1995; Pressley & Hilden, 2004; Someren, Barnard, & Sandberg, 1994). This methodology has been used extensively to learn about the strategies people use to solve mathematical and physics problems (Case, Harris, & Graham, 1992; Chi, et al., 1981; Clement, 1982; Redish & Steinberg, 1999) and the reading processes adults and children use to comprehend text (Afflerbach, 1990; Caldwell & Leslie, 2006; Johnston & Afflerbach, 1985; Laing & Kamhi, 2002; Pressley & Hilden, 2004; Stromso, Braten, & Samuelstuen, 2003).

The selection of this particular methodology aligns with the study's purpose. Since the overall goal of this research is to determine how students interact with different texts and, specifically, if and how students make inferences while doing so, I needed to select a research methodology that would capture participants' cognitive processing and provide them with opportunities to engage in inference generation. Study participants verbalized their thoughts as they interacted with each text and made sense of the ideas presented. As other research has shown (e.g., Caldwell & Leslie, 2006; Gilabert, Martinez, & Vidal-Abarca, 2005; Noordman, Vonk, & Kempff, 1992; Stromso, et al., 2003), this sense-making process is likely to involve the generation of inferences to construct a mental representation of the texts.

Verbal reports can be made either concurrently or retrospectively (Ericsson & Simon, 1984). Concurrent verbal reports occur during the process of engaging in a task and require that the participants decide when to stop and think aloud (the assumption is that they will stop and verbalize their thinking when a thought has entered their short-term memory). Retrospective verbal reports either follow task completion or occur during engagement with the task at predetermined stopping points. Ericsson and Simon (1984) recommend concurrent verbal reports because these reports are more likely to capture the thoughts in one's short-term memory and are most closely linked to one's thought processes. However, many think aloud studies of reading comprehension require readers to stop and think aloud on cue. In addition, some studies have found that young students have a more difficult time verbalizing their thoughts concurrently and need to be given more support, usually in the form of cues, to do so successfully (see Afflerbach & Johnston, 1984). It is for this reason that I decided to use retrospective verbal reports during task engagement where students were given frequent reminders to stop and think aloud so that they could have multiple opportunities to share their thinking.

Another feature of verbal reports is the extent to which the researcher interacts with the person thinking aloud. In particular, science education researchers have used verbal reports to understand students' reasoning about various scientific topics and processes (Hogan & Fisherkeller, 1999). These verbal reports are captured as students respond to performance assessments, for example, recording students' conversations as they solve electricity problems in pairs (Kelly, Druker, & Chen, 1998), or as students conduct experiments and collect data (Nakhleh & Krajcik, 1993), with minimal interaction with the researcher. However, sometimes reports are gathered when the researcher takes a more active stance by probing students with questions or engaging in purposeful conversation with students. These "interactive" protocols go beyond the students' independent sense-making practices and yield information that might otherwise go unspoken, perhaps even not thought of. The use of probes has the potential to influence students' thinking and reasoning, producing perhaps an authentic conversation but not necessarily reproducing a thought process that the child would engage in independent of the observer.

In this study, I used retrospective, non-interactive verbal reports with participants; students were cued to stop and think aloud after reading each sentence and asked to report what they were thinking as they made sense of the texts. However, I also encouraged students to stop at any point and share their thoughts about what they just read, as well as to continue reading if they were not thinking anything at the predetermined stop points. I did not probe students to expand upon their think aloud comments because I did not want to draw their attention to particular claims or ideas. I was interested in learning about what strategies students used when interacting with these texts *unprompted* and worried that any interference could change their think aloud comments, which served as the study's primary data source.

Predictions Regarding the Relationship between Individual and Text Characteristics, Students' Strategy Use, and Comprehension

Reading science informational and data texts are interactive processes that require one to engage in sense-making practices. When processing the texts in this study, students are expected to generate inferences to create a mental representation of each text. As discussed above, students' strategy use, particularly the types, frequency, and source of the inferences they generate, is related to various individual and text characteristics. Research findings suggest that variability in students' strategy use is also related to their comprehension; that is, students who engage in more inference generation have higher comprehension. Figure 2.1 presents a conceptual model detailing the theorized relationships between these individual and text characteristics, students' strategy use, and comprehension. In this section, I describe and explain hypotheses for this research study, based upon past research findings.

When reading the informational and data texts, I predict that the frequency and sources of inferences will interact with students' prior knowledge and text type. In particular, I predict that there will be a difference in the types of inferences generated most frequently across text types (informational versus data texts), which will be a function of text features. The informational texts present scientific knowledge in terms of facts about the topic and are written using a generalizing quality. As a result, I predict that students' inferences while reading the informational texts will consist primarily of associations, which require students to make text elaborations.

In contrast, the scientific data texts report actual observations of real-life phenomena and, thus, are more likely to prompt students to engage in pattern finding. When interpreting these observations, students might be more likely to ask themselves about patterns across different observations and why these patterns exist in the data; the scientific data texts may even prompt students to predict patterns for subsequent observations. As a result, I predict that students' reading of scientific data texts will

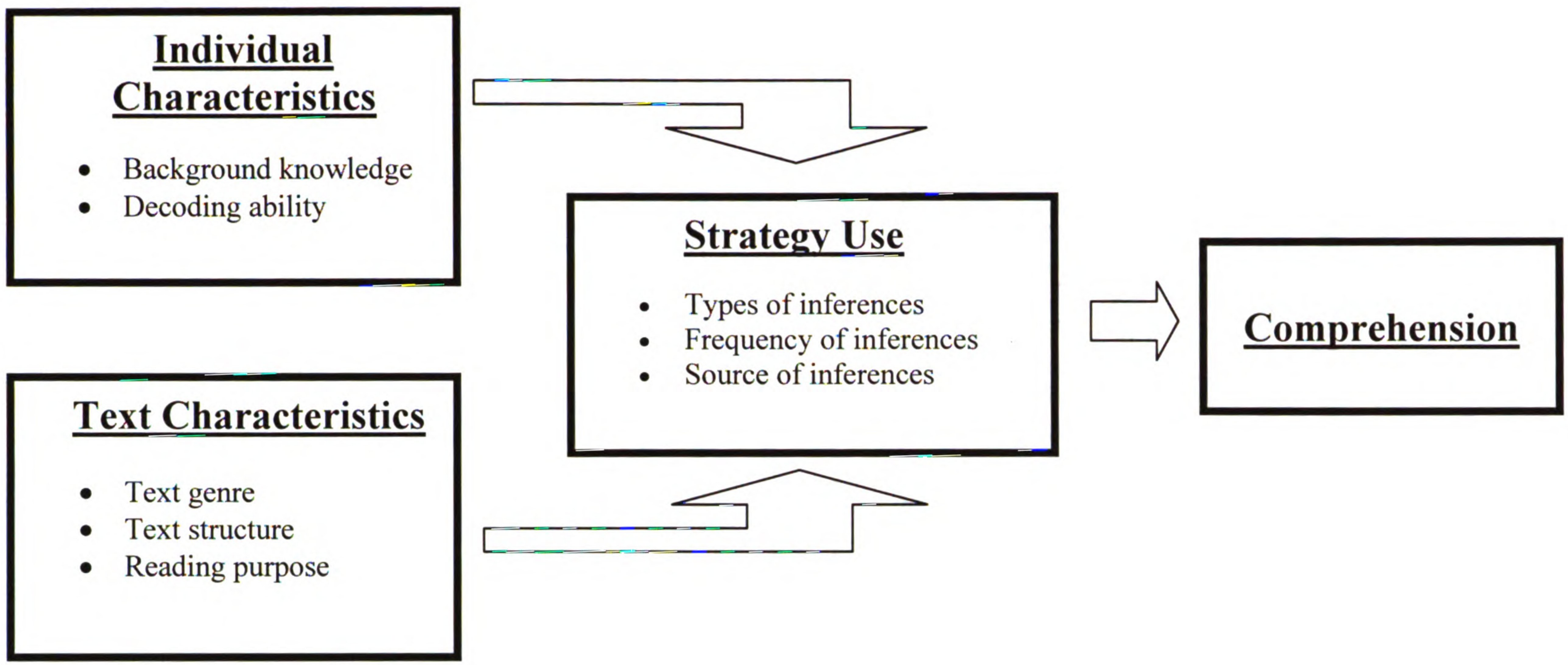

Figure 2.1. Conceptual model for the relationship between individual and text characteristics, students' strategy use, and comprehension

involve more explanations and predictions compared to their reading of informational texts. Moreover, for both text types, I predict that students with higher prior knowledge will make more inferences overall because they have more experiences and ideas to draw upon.

In terms of the relationship between students' strategy use and their text comprehension, I predict that students who generate more inferences while reading each text will show higher levels of comprehension. Kintsch's construction-integration model shows that inference generation is a key component of developing a mental representation of the text, which supports students' text comprehension. I expect to see a moderate to strong relationship between students' inference generation and comprehension for each text. In addition, I predict that particular types of inferences will be more important in this relationship. That is, students who generate more explanations will also have higher comprehension scores; this is because explanations address the causal reasons for phenomena and this connection between theory and evidence is so important to developing students' scientific understanding.

Chapter 3: Methods

As discussed in the previous chapter, I used think aloud methodology to examine the strategies elementary students used when reading informational and data science texts. In this chapter, I provide details about the study's sample, data collection instruments and procedures, and data analysis. I begin by describing the study participants and their selection and then turn my attention to the data collection procedures and data instruments.

Sample Selection and Description

To find study participants, I contacted elementary principals and third grade teachers in local school districts to explain the purpose of the study and to solicit principal, teacher, and student participation. To begin, I made initial contacts with third grade teachers with whom I have worked directly or indirectly through various research projects, teaching assignments, and professional development experiences at the university. Then, I recruited additional teachers through principal recommendations. Twelve third-grade teachers from ten different schools across four school districts located within or near a mid-size Midwestern city expressed interest in having their students participate. Table 3.1 provides basic background information regarding the general student population at each school.

After finding teachers who were interested in participating, I followed a two-step process to select student participants. The first stage used teacher recommendations. Research has shown that students' ability to recognize and read words fluently impacts

Table 3.1. School-Level Data for Participating Classrooms

Classrooms	Type	Enrollment[a]				Free/Reduced Lunch Eligibility[a]
		White	Black	Hispanic	Asian/Pacific Islander	
A, B, & C	Suburban/Public	88.4%	2.7%	2.4%	6.5%	16.9%
D	Urban/Private	83.6%	1.1%	15.3%	0.0%	Not available
E	Suburban/Public	59.8%	25.1%	4.6%	10.5%	34.4%
F	Suburban/Public	86.5%	4.5%	3.5%	5.5%	14.2%
G	Suburban/Public	80.3%	9.3%	7.3%	3.1%	37.1%
H	Suburban/Public	85.9%	6.3%	5.1%	2.7%	28.2%
I	Suburban/Public	82.9%	10.7%	5.5%	1.1%	42.1%
J	Urban/Public	67.9%	12.5%	18.2%	1.4%	82.4%
K	Urban/Public	38.8%	38.8%	18.1%	4.2%	62.7%
L	Urban/Public	40.1%	34.2%	18.7%	7.0%	51.5%

Note. [a]Information obtained from the National Center for Education Statistics Common Core Data 2007-2008 school year (accessed at http://nces.ed.gov/ccd/).

their reading comprehension (Drum, Calfee, & Cook, 1981; Paris & Hamilton, 2009; Perfetti & Hogaboam, 1975; Stanovich, 1996). Since reading these texts relies on students' ability to accurately decode and make sense of written text, only students who were reading at or above grade level and did not have any identified reading or learning difficulties (e.g., poor reading comprehension, dyslexia, other learning disability) could participate. Teachers used both formal and informal measures of students' reading ability to identify students meeting these criteria. These measures included teachers' classroom observations, running records, oral and written responses to reading comprehension questions, and information from district and state assessments (e.g., directed reading assessment or other reading diagnostic tests).

In the next stage, teachers asked all or some of the students in their classes who met the study criteria to participate; the teachers then gave those students who expressed interest a parental consent form to complete and return. Some teachers opted to invite only a few students from their classroom to participate, mainly due to the time commitment for participation and scheduling restraints, while other teachers sent the forms home with all the students in their class who met the criteria. Only those students who returned a signed parental consent form and met the study criteria participated in this study. The initial sample included 87 third grade students. However, two students opted to discontinue their participation following the initial prior knowledge interview. Another student was unable to engage in the think aloud process, even after two modeling and practice sessions. Thus, the final sample included 84 third grade students who were reading either at or above grade level and had no identified learning disabilities.

Overall, 40 males (47.6%) and 44 females (52.4%) participated in this study. Fifty-nine (70.2%) were White, 15 (17.9%) were Black, 7 (8.3%) were Hispanic, and 3 (3.6%) were Asian/Pacific Islander. At the time of the study, students' ages ranged from eight years old to ten years old (59 eight year olds, 24 nine year olds, and one ten year old). Fifty students (59.5%) were reading at grade level and 34 students (40.5%) were reading above grade level, according to their teachers' reports. Twelve students spoke English as a second language, but only four received specialized English for Language Learners (ELL) instructional support at their schools. No additional student background information was collected. Table 3.2 provides student background information for study participants by classroom.

Data Collection and Instruments

In this study, I met individually with each student on two separate occasions to complete data collection. In the first session, I conducted the prior knowledge interview on sound and plants. During the second session, which occurred approximately a week later, I introduced students to the think aloud methodology using practice texts, provided opportunities for students to read and think aloud with the four texts in this study, and asked comprehension questions following each text. During each session, I used an audio recorder to record students' oral comments and later transcribed their comments. In this section I will describe the material or data source in the order which they were used and explain how each was used for data collection purposes. Table 3.3 provides a summary of the materials and data sources used.

Prior knowledge interviews. Approximately a week before they read the four texts, I assessed each student on his or her prior knowledge relating to the two science

Table 3.2. Student Background Information for Study Participants by Classroom

Classroom		Gender		Ethnicity				Reading Level	
	Total	Male	Female	White	Black	Hispanic	Asian/Pacific Islander	At Grade Level	Above Grade Level
A	11	7	4	9	1	1	0	6	5
B	9	3	6	7	0	2	0	6	3
C	2	1	1	1	1	0	0	1	1
D	8	3	5	8	0	0	0	4	4
E	6	1	5	2	2	0	2	4	2
F	6	3	3	6	0	0	0	6	0
G	15	10	5	12	1	1	1	4	11
H	3	0	3	3	0	0	0	3	0
I	5	3	2	3	2	0	0	3	2
J	6	4	2	3	2	1	0	5	1
K	5	2	3	3	2	0	0	4	1
L	8	3	5	2	4	2	0	4	4
Total	84	40	44	59	15	7	3	50	34

Table 3.3. Materials and Data Sources Used in the Study

Materials or Data Source	Description	Purpose	Time Administered
Prior knowledge interviews	Set of four to five open-ended questions addressing key concepts related to particular science topics (sound and plants)	To assess students' understanding of key concepts related to particular science topics to be encountered in the informational and data texts	One or more weeks prior to engagement with the informational and data texts
Think aloud introduction protocol	Demonstration of think aloud methodology and use of practice texts	Provide students with opportunity to practice using think aloud methodology	Immediately prior to engagement with the informational and data texts
Informational texts	Students read informational text to address specific purpose (e.g., explain how an oak tree grows or how sound is made)	To understand strategies and types of inferences students generate and knowledge sources used *unprompted* when reading informational texts	Either preceding or following data texts (depending on assigned condition)
Data texts	Students interpret secondhand scientific data to address specific purpose (e.g., explain how a pumpkin plant grows or how sound is made)	To understand strategies and types of inferences students generate and knowledge sources used *unprompted* when reading data texts	Either preceding or following informational texts (depending on assigned condition)

Table 3.3 (cont'd).

Material or Data Source	Description	Purpose	Time Administered
Comprehension questions	Set of six questions per text probing students' understanding of explicit and implied concepts and ideas from the text	To assess students' literal and inferential understanding of texts	Immediately following each text

topics (sound and plants). Each prior knowledge assessment consisted of four to five open-ended questions focused on important concepts. For the sound assessment, I asked students to identify situations when sound is and is not made, to explain how sound is made, to identify what part of an instrument makes sound, and to explain how to change the volume and pitch of sound and why the sound changes in these ways. During the sound assessment, I had a rubber band instrument (shoebox with open top and two rubber bands around it) available for students to use (for question three only) and refer to while answering questions three, four, and five. I did so because I wanted to make sure that every student understood what I meant when I referred to a "rubber band instrument" in the prompt for these questions. For the plants assessments, I asked students to identify examples of plants and non-plants, to identify and explain the function of different plant parts (e.g., roots, stem, leaves), to identify and explain the role of different plant requirements (e.g., air, water, nutrients), and to describe the different stages in a plant's life cycle. During the plants assessment, no objects were available for reference. I assumed that students were likely to have prior experiences with different kinds of plants and could draw upon these experiences without having an actual plant in front of them to refer to during this interview. I also worried that providing a single example of an actual plant might limit what students say when responding to these questions (e.g., only focus on the features of that specific plant and what the parts they could see). These questions target key concepts about each topic that one might draw upon when reading the informational and data texts; thus, this background knowledge is one potential source of inference generation during text engagement.

I relied upon teachers' curriculum guides and instructional resources to design these questions and ensured that the questions addressed the relevant concepts identified at the state and national level for that topic at the elementary level. Appendices A and B provide a list of the relevant state and national content standards along with the interview questions for each topic. I will discuss details about how I assessed and scored the students' responses in the data analysis section.

Think aloud introduction protocol. Researchers using the think aloud methodology frequently teach their subjects what it means to engage in think aloud verbal reports prior to data collection. This introduction typically involves some type of verbal explanation and demonstration of the think aloud process as well as an opportunity for the subjects to practice the think aloud process with novel problems, tasks, or texts. It is common for researchers to have subjects practice thinking aloud with additional problems, tasks, or texts until the subjects have reached a level of proficiency, usually based on the researcher's assessment (Kucan & Beck, 1997; Someren, et al., 1994).

Since my study participants are young children who likely have limited experience with thinking aloud, I included both a demonstration of this method and practice opportunities prior to introducing the texts used in this study. In order to ensure that the students were able to comprehend a text while engaged in the think aloud process, I asked them to respond to an open-ended question regarding the content of the practice text after reading. More modeling and practice ensued if students did not successfully engage in thinking aloud while reading or if their response to the comprehension question did not show a basic understanding of text ideas. Appendix C provides the directions, demonstrations, and practice texts for the think aloud introduction.

Informational and data texts. For each topic, each student interacted with one informational science text and one data text. This design allowed me to examine how the strategies students used to comprehend the texts, specifically the inferences they generated, was related to the different content topics as well as different text types. Appendices D to G present the texts and task directions used.

In order to understand students' thinking, specifically what strategies they used to comprehend the text and what types of inferences, if any, they generated, students stopped after reading aloud each sentence in the texts and verbalized their thoughts aloud. A visual cue (e.g., the word STOP) was inserted at the end of each sentence to remind the students to stop and think aloud at this point. Therefore, the number of stops equaled the number of sentences in each text. I asked students to "tell me what you are thinking about what you just read" whenever they saw the word STOP.

Since some inferences tend to be generated automatically while other types of inferences may only be generated in goal-specific situations, each text interaction was goal-directed in order to allow for the greatest diversity in inferences generated. I set similar goals for each text – to be able to tell another student how sound is made or how plants, specifically an oak tree or a pumpkin plant, grow. I told students about these goals when giving directions in order to provide a meaningful goal-directed purpose for their text interactions. At the beginning of each new reading, I covered the whole text with a blank piece of paper. Then, students moved the paper down to reveal one sentence at a time as they read each text. The texts that I used with the students only had one sentence written per line (unlike the texts shown in the appendices). Sentences that they had already read remained in view and could be referred back to during subsequent think aloud comments. In addition, prior to reading the sound data text, I visually showed each student the three sound systems (e.g., thumb plucker, rubber band strummer, and ruler on edge of table) and these three objects remained visible during reading. No other objects were available for students to refer to during the reading of the other texts.

I randomly assigned each student to one of four possible conditions. In each condition, the student read and responded to each text, but the order of text presentation varied. These conditions were counterbalanced across both topics and text type. Table 3.4 shows the order for reading the texts in each condition and Table 3.5 provides details about the condition assignment for study participants by classroom.

Table 3.4. Conditions for Data Collection

	Condition One	Condition Two	Condition Three	Condition Four
First Text	Informational – Sound	Informational – Plants	Data – Sound	Data – Plants
Second Text	Informational – Plants	Informational – Sound	Data – Plants	Data – Sound
Third Text	Data – Sound	Data – Plants	Informational – Sound	Informational – Plants
Fourth Text	Data – Plants	Data – Sound	Informational - Plants	Informational - Sound

Table 3.5. Condition Assignment for Study Participants by Classroom

Classroom	Condition One	Condition Two	Condition Three	Condition Four
A	2	3	3	3
B	2	2	2	3
C	0	0	1	1
D	2	2	2	2
E	2	2	1	1
F	1	2	2	1
G	4	4	3	4
H	1	0	1	1
I	2	1	1	1
J	1	2	2	1
K	1	1	2	1
L	2	2	2	2
Total	20	21	22	21

Research findings have revealed that features of text can impact text comprehension and inference generation. As a result, I selected the informational texts and designed the scientific data texts to meet certain criteria. The informational text came from published informational texts on these topics while the data texts were developed using suggestions from teachers' curriculum guides and examples of students' observations of similar phenomena. All four texts have similar readability levels that are appropriate for the grade level of students. That is, third grade students who are reading at or above grade level should have minimal difficulty decoding the words in each text. In this study, the readability levels of these texts ranged from a low of 2.29 for the plants informational text (beginning to mid-second grade) to a high of 3.32 for the sound data text (beginning to mid-third grade). Since I conducted this study during the second part of the school year, the third grade students in this study should have minimal difficulty decoding the words in the texts. I selected informational texts that represent reading materials classroom teachers might actually use. I also provided second-hand observations of scientific phenomena that closely mimicked actual data students at this grade level would likely collect if they were studying these particular topics in their classrooms. Moreover, I selected informational texts that are well organized and rely upon scientific facts to describe real-world phenomena. Finally, I decided to remove all illustrations, photographs, and diagrams from the texts. Although these features are frequently present in informational texts, I eliminated them for this study because research has shown that these graphical aids are a potential source of variability that could influence students' strategy use (R. R. Norman, 2010). I wanted to isolate the variables that might influence the strategies students use as they read each text. Descriptive information about each text is provided in Table 3.6.

Table 3.6. Descriptive Information on Texts Used in the Study

Topic and Text Type	Number of Sentences	Number of Words	Grade Level Readability[a]	Key Features
Sound Informational	17	115	2.95	-Description of multiple sound concepts -Topical organization -Timeless verb construction -Generalizing quality -Abstract in nature -Substantial technical vocabulary
Sound Data	17	222	3.32	-Observations of three objects making sound -Topical organization -Uses table to display observations -Minimal technical vocabulary
Plants Informational	19	138	2.29	-Description of growth of single plant (oak tree) -Temporal organization -Timeless verb construction -Generalizing quality -Some technical vocabulary
Plants Data	15	167	2.67	-Observations of single plant (pumpkin plant) at specific points in time -Temporal organization -Uses table to display observations -Some technical vocabulary

Note. [a]To calculate the grade level readability for each text, I used the Flesh Kincaid grade level readability formula, which provides a measure of the approximate grade level needed to comprehend the text (accessed at http://www.online-utility.org/english/readability_test_and_improve.jsp).

Sound informational text. The sound informational text provides information about three key concepts: 1) how sound is made, 2) how sound changes pitch, and 3) how sound changes volume. The text explains each concept by mentioning relevant attributes of each concept and giving examples to illustrate the concept. For example, in the section about changes in pitch, the text reads (Olien, 2003):

> Sounds can have a high or low pitch.
> Fast vibrations make high-pitched sounds.
> A bird chirps a high sound.
> Air in its throat vibrates fast.
> Slow vibrations make low-pitched sounds.
> A lion's roar is low.
> The air in a lion's throat vibrates slowly.

In this section, the author identifies what type of pitch sound can have (high or low), describes what causes each type of pitch (i.e., fast or slow vibrations) and gives an example of an animal that makes these different pitched sounds (i.e., bird or lion).

The text itself is written with a "generalizing quality" (Duke & Bennett-Armistead, 2003, p. 17), meaning information is presented in a way that implies generalizability across contexts or situations. For example, the first sentence states that "objects make sound when they move." This sentence implies that it does not matter what type of object it is or how the object moves, but that movement is the key to sound production. Also, the sound informational text uses some technical vocabulary related to sound (i.e., vibrates, sound wave, pitch, volume, high-pitched, low-pitched, loud, quiet) that one might expect when reading a text about sound.

After reading the sound informational text, there are several key ideas that students should understand: 1) sound is made when objects vibrate, 2) when objects move they vibrate the air, 3) to hear the sound a sound wave moves through the air and travels to your ear, 4) sound can have different pitches (high or low) and volume (loud or quiet), 5) high pitched sounds are made when air vibrates fast, 6) low pitched sounds are made when air vibrates slowly, 7) big sound waves make loud sounds and vibrate more air, 8) quiet sounds vibrate less air than loud sounds, and 9) sounds become quieter as sound waves move away. This text contains considerably more concepts, and these concepts tend to be more abstract in nature (e.g., focused on developing students' model-based reasoning to explain this phenomena), as compared to the other three texts.

Sound data text. The sound data text uses a graphical device, a table, to present a student's observations about what he saw, heard, and felt when making sound using three different sound systems. The table includes three rows, one for each of the objects that make sound (thumb plucker, rubber band strummer, and ruler on edge of table), and columns stating observations about "what I see," "what I hear," and "what I feel." In the sound data text, the observations are written in first person and detail what the student saw, heard, and felt when making sound with each object. All of the observations about what the student saw identify what part of the object moved and describes how it moved (e.g., "I see the popsicle stick moving up and down.") while the observations about what the student felt describes what he sensed as he touched the moving object (e.g., "I feel the rubber band tingle my fingers."). The observations about what the student heard describe changes in volume and/or pitch for each object. For example, the student's observations about what he heard with the thumb plucker were:

> I hear the popsicle stick hitting against the wood block. When I pluck the long popsicle stick I hear a low sound. When I pluck the short popsicle stick I hear a high sound. When I push down hard on the long popsicle stick and let go I hear a loud sound. When I push down gently on the long popsicle stick and let go I hear a soft sound.

The sound data text uses minimal technical vocabulary (e.g., low, high, loud, soft). There are several key ideas that students should be able to comprehend from the sound data text. These ideas are: 1) sound is made when objects move, 2) you need to do something to an object to make it move, 3) sound can be high, low, loud, or soft, and 4) you can move objects in different ways to create these different types of sound, 5) how to make different pitched sounds, and 6) how to make sounds of different volumes.

Plants informational text. The plants informational text provides information about how an oak tree grows from a seed. Like the sound informational text, the plants informational text does not use any graphical devices (e.g., chart, table, headings) and is written with timeless verb construction. The timeless verb construction means that the statements are written in a way to make them seem generalizable to all oak trees; that is, every oak tree has "acorns drop on the ground in the spring" and "flowers [that] help make acorns." However, unlike the sound informational text, this text is organized in a process oriented, temporal, and linear fashion; it focuses on a single plant (in this case an oak tree) and details the various stages in the oak tree's life cycle from start to finish.

Essentially, the plants informational text presents the life cycle of an oak tree by describing the main events in this process. The plants informational text begins by stating that "acorns grow on oak tree branches" and continues by describing what happens to the acorn as it grows to be a large oak tree. The text continues by detailing the main stages in the oak tree's life cycle, including the acorn cracking open, a shoot and sprout growing from the acorn, and the tree growing larger and producing leaves, flowers, and acorns. There is some topic specific vocabulary present in the plants informational text (i.e., acorns, seeds, shoot, sprout, leaves, flowers, branches), but these words are more likely to be familiar to students than the vocabulary in the sound informational text. The main ideas that students should comprehend from this text are: 1) acorns are the seeds of an oak tree, 2) there are particular stages in the life cycle of an oak tree (seed → shoot → sprout → leaves → flowers → acorns) and these stages occur in a specific order, 3) there is a cyclical nature to an oak tree's growth, and 4) the oak tree has various parts that grow and change over time.

Plants data text. The plants data text also describes how a particular plant (in this case a pumpkin plant) grows from a seed to a fruit, but does so using a student's firsthand observations of steps in this process at specific points in time. This text is organized in a temporal sequence and the student's observations are presented using a table with two columns – one for the specific point in time (e.g., day 1, day 60) and another for written observations about what the plant looks like at that time (e.g., for day 60 the text states, "I see that the plant has flowers now."). Like the sound data text, each observation is written in the first person and states objectively what the student noticed at that moment in time. For example, the first three rows provide observations from day one, seven, and twenty:

Day One:	I see a black and gray seed sitting in the dirt. The seed is deep down into the ground.
Day Seven:	I see a little green stem starting to pop up out of the seed. The seed is starting to break apart a little bit. The roots planted themselves into the ground.
Day Twenty:	I see a green stem that has poked out of the soil and grown upward out of the dirt. There are two leaves on the plant and the roots have grown much bigger.

The observations begin on day 1, when the seed is "sitting in the dirt" and "down into the ground," and continue on through the major growth stages, including the growth of the roots, stem, leaves, flowers, and pumpkins. The plants data text also uses many topic-specific vocabulary words to name the plant parts (i.e., roots, seed, stem, leaves, flowers, pumpkins) and some to detail what is happening to the plant (i.e., grow, harvested). After reading the plants data text, students should understand: 1) that a pumpkin plant goes through particular stages in a specific order as it grows (seed → roots → stem → leaves → flowers → pumpkin), 2) how the different parts of a pumpkin plant change as it grows over time, and 3) the seed produces the pumpkin plant.

Comprehension questions. Immediately after reading each text, students answered a series of questions to assess their understanding of the ideas presented in the informational and data texts. I included both explicit questions that target ideas directly stated in these texts and implicit questions that ask students about ideas implied in the texts. Appendix H lists the comprehension questions I asked regarding each text, including whether each one is an explicit or implicit question.

Students did not have access to the texts while answering the comprehension questions. I purposefully removed the text from view during this time because I wanted to assess students' recall and interpretation of text ideas, not their ability to locate the answers in the text (especially for the explicit questions). I used these questions as a proxy for whether students constructed both a text base and situation model, which are the two levels of representation in Kintcsh's (1988) model of text comprehension. The text base level of representation, assessed by the explicit questions, focuses on readers' understanding of individual ideas, while the situation model, assessed by the implicit questions, pinpoints readers' integration of text ideas.

The explicit questions asked students to recall information that they read in the text. For example, after they read the sound informational text, I asked students to identify when objects make sound (when they move/vibrate), describe what a sound wave is (moving air), and identify what kind of pitch sound can have (high or low); all of these ideas were explicitly stated in the written text (see sentences one, three, and five). The implicit questions required students to make inferences based on the information in the text; students will not be able to answer the questions by finding the answer stated directly in print, although they might rely on text information to answer the implicit questions accurately. For example, after reading about the student's observations of what happens to a pumpkin plant as it grows over time, I asked students to explain why the seed breaks apart (so the plant can grow), why the roots grow into the ground (to get water for the plant and/or secure the plant in the ground), and why the pumpkin plant grows flowers (to make the pumpkins). These three implicit questions required students to draw upon text ideas and their background knowledge to generate appropriate answers.

Data Analysis

This study uses a mixed methods approach, combining both qualitative and quantitative analysis techniques (Creswell, 2009). Specifically, I designed and used coding schemes to provide descriptions of students' text interactions, their prior knowledge, and text comprehension. I used descriptive and inferential statistics to examine how students' text interactions varied, if at all, as a function of text type and topic, and how these interactions related to students' prior knowledge and comprehension. In this section, I discuss details about the specific analyses related to students' text interactions, prior knowledge, and comprehension and describe how I used this information to explore the relationships between these variables.

Students' text interactions. The first research question focuses on the strategies, specifically the types of inferences, third grade students use when reading two different types of science texts – informational and data texts – across two different science topics - sound and plants. The second research question examines how text type and topic interact with students' strategy use. To fully explore the data, I also investigated the inaccurate ideas students stated and differences by gender and condition.

Research has shown mixed results in terms of gender effects related to students' interaction with different texts and their comprehension (Brantmeier, 2003; Chambers & Andre, 1997; Chiu & McBride-Chang, 2006; Spence, Yore, & Williams, 1999). Some findings have shown gender differences on comprehension tasks, especially when text content is taken into consideration, while other findings have found no gender differences related to students' recall of text ideas or shown that different variables can mediate gender effects related to students' text comprehension. In addition, there have been debates in the science education and literacy communities regarding the role of informational texts in science classrooms (Cervetti, et al., 2006). Some researchers and practitioners strongly advocate for providing students with multiple opportunities to interact with firsthand and secondhand data before being introduced to complex, and often abstract, scientific concepts in texts. The main impetus behind this push is twofold. First, one assumption is that students will better understand the scientific concepts if they have a chance to identify patterns in data and hypothesize potential explanations for these patterns before learning about scientific concepts and models. Second, science educators argue that students will be more likely to understand how scientific knowledge is constructed and develop understanding of the nature of science if they have opportunities to investigate real-world phenomena prior to reading about scientific claims.

To answer these questions, I first developed and refined qualitative coding schemes to categorize students' think aloud comments, the knowledge sources they relied upon to generate inferences, and the accuracy of their idea statements. Then I used the coded data to conduct various statistical analyses. Below, I describe the coding schemes and analyses for the think aloud comments, knowledge sources, and inaccurate ideas.

Think aloud comments. First, I started with Trabasso and Magliano's (1996) coding scheme for inference generation to identify the types of inferences students made during each text interaction. Trabasso and Magliano identified three types of inferences in their framework for analysis of conscious understanding: explanations, predictions, and associations. Explanations are inferences that provide answers to "why" questions and are used to connect the current sentence with previous text information or prior knowledge. Predictions are inferences that state the readers' expectations regarding subsequent information in the text or steps in a process, while associations are inferences that serve to elaborate ideas introduced in the text. Trabasso and Magliano's coding scheme also included statements that would not be coded as inferences; these comments include paraphrases (reproductions or restatements of text ideas) and metacomments (comments about their understanding of ideas in the text or personal opinions regarding these ideas). I included these other two comment types in the coding scheme.

However, students' think aloud comments revealed additional interactions not captured by this coding scheme. As a result, I revised the coding scheme to include these text interactions as well, including codes for: question, visualize, incomprehensible, personal connection, and personification. Table 3.7 provides descriptions and examples of the different types of think aloud comments from the study.

To code the students' think aloud comments, I first parsed each comment into idea statements and then examined each idea statement to determine its relationship to the focal sentence (e.g., to explain, predict, associate, paraphrase, question, etc.). For example, after reading the sentence "Big sound waves make louder sounds," one student commented that, "Bigger sound waves make louder sounds. Smaller sound waves make little littler sounds." I parsed the students' think aloud comment into two separate idea statements (the first sentence was one idea and the second sentence was another idea) and then coded each one separately in relationship to the focal, or text, sentence. I coded the first idea statement as a paraphrase, since the student essentially restated the same idea, and the second idea statement as a prediction because the student was stating his expectation regarding subsequent events.

Following coding of students' text interactions, I determined the total number of ideas stated and the number of each type of comment generated per student per text (e.g. total number of explanations for the sound informational text). I used a two-factor repeated-measures analysis of variance (ANOVA) to examine the interaction of text type (informational and data) and topic (sound and plants) with students' strategy use. Specifically, I tested to see if there was a main effect of text type (e.g., on average, do students make a statistically significantly different number of paraphrases when

Table 3.7. Descriptions and Examples of Think Aloud Comments

Type of Comment	Description	Examples: Text Prompt	Examples: Think Aloud Comment in Response to Text
Explanation	Student provides causes or reasons why something occurs or identifies conditions for current state of an object or event.	A lion's roar is low.	Because, um, the vibration is going like really slow.
		There are two leaves on the plant and the roots have grown much bigger.	Cause when the plant gets a little bigger it needs a more roots for it to get more water up to it.
Prediction	Student states expectations regarding subsequent information in the text or about upcoming steps in a process.	Sounds are louder when they are close.	So…if they're farther away…you can't hear them very well.
		An oak tree begins to grow.	Then the stem gets bigger. It begins it begins to kind of like harden and like get bigger.
Association	Student elaborates on ideas presented in text.	You hear sound when the wave enters your ear.	I can, um, when it enters your ear it hits your ear drum
		Acorns grow on oak tree branches.	Some, well, it's like a life cycle of a…fruit. Some fruits have seeds and they will go on the ground and usually they would go into the soil.

Table 3.7 (cont'd).

Paraphrases/ reiteration	Student restates or reproduces ideas or phrases in the text.	Objects make sounds when they move.	There has to be movement in the object to make sound.
		Acorns grow on oak tree branches.	So I think a- a plant and that oak tree and then acorns start coming out from it.
Metacomment	Student provides personal comment about his/her understanding of or personal opinions about text ideas.	Sounds are louder then when they are closer.	Yes, true.
		The acorn is now an oak tree.	I don't know how that's possible, but.
Question	Student asks questions about ideas presented in the text.	A lion's roar is low.	I wonder why a lion's roar is low not soft not high.
		Day 90. I see small pumpkins where the flowers used to be.	Are they green?
Visualize	Student creates an image or picture in his/her mind prompted by ideas or information presented in the text.	Rubber band strummer. I see the rubber band shaking from side to side.	And like a little fly decided go swinging and instead it goes swinging on that.
		A shoot becomes a root of an oak tree.	The roots, um, I can picture the roots coming out of the plant.

Table 3.7 (cont'd).

Incomprehensible	Response is unclear and difficult to understand.	The air in a lion's throat vibrates slowly.	The ??? doesn't have any good.
		Acorns are the seeds of an oak tree.	And then oak oaks come on the tree oak trees.
Personal Connection	Student describes or mentions a connection to his/her life experiences sparked by the text. These responses do not elaborate on text ideas.	Beating a drum vibrates in the air.	Well, my cousin Louis he's, uh, four years old and he has drums and then one time I had came over his house and I had played the drums.
		I see big pumpkins that are ready to be harvested.	My mom, um, has like on Facebook and there's something called Farmville and she wants to buy a harvester. And she planted pumpkins.
Personification	Student gives real-life characteristics or intentions to an object.	The shot pushes itself into the ground.	It's like wants to like relax and stuff like that.
		I see a black and gray seed sitting in the dirt.	It's laying in the dirt like taking a nap.

interacting with the informational texts as compared to the data texts?), a main effect of topic (e.g., on average, do students make a statistically significantly different number of predictions when interacting with the sound texts as compared to the plants texts?), and an interaction effect of text type by topic (e.g., is there an interaction effect between the text type and topic in terms of the number of explanations students generate?). In this study, I used a .05 significance level for all the statistical tests (ANOVA and correlations).

In addition, I was interested in whether there were any effects from two of the between-subjects factors (gender and condition) on these results. It is possible that males and females could interact with these texts in varied ways or that patterns in students' text interactions might be different depending on whether students interacted with the informational or data texts first. As a result, I tested to see if the total number of each comment varied by gender (e.g., comparing the mean number of explanations produced by males versus females) and condition (e.g., comparing the mean number of explanations for students across conditions one to four). This part of the analysis addresses the question of whether gender and order matters for how students interact with the different texts overall. Overall, I found that patterns in students' text interactions were not different by gender or condition, so I did not report or discuss these results in the following chapters. I also examined any higher order effects of gender and condition by topic, type, and topic by type and found that there were two higher order effects related to the mean number of predictions, one higher order effect related to the mean number of associations, and two higher order effects related to the mean number of paraphrases. Appendices I to J provide additional information on these higher order effects.

Knowledge sources. For each inference a student generated, I identified and coded the knowledge source he or she relied upon. When producing explanations, predictions, and associations, students relied upon three different knowledge sources: 1) the *activation* of their prior knowledge, 2) the *maintenance* of an idea from a recent sentence in that text or recent think aloud comment produced while reading that text, or 3) the *retrieval* of an idea from prior text ideas or think aloud comments within that text. The major distinction between the last two categories rests in the proximity of the stated idea to its first appearance. If the stated idea came from the written text or think aloud comment no further than two sentences away, then I coded the statement as maintenance of an idea, since the student is likely still holding that idea in their short term memory. However, if the stated idea was drawn from a prior text statement or think aloud comment more than two sentences away, then I coded the statement as retrieval of an idea, since it was more likely that the student was drawing this idea from their long term memory.

I provide illustrative examples of the first two types of knowledge sources by using the think aloud comments one student produced while reading the sound informational text. One sentence near the beginning of this text describes what a sound wave is. This student activated his prior knowledge to elaborate on this text idea, stating that "sound waves travel in your ears." This information about where sound waves go was not previously stated in this text or in the students' prior think aloud comments, so I coded the knowledge source for this association as activation of prior knowledge. Then, later on, the text describes how high pitched sounds are created (e.g, fast vibrations) and gives an example of an animal that makes high pitched sounds (e.g., bird). After that, the text mentions that the "air in its [bird's] throat vibrates fast." The student explained that the air in the bird's throat vibrated fast "to create...high-pitched sound waves." This explanation relied upon information that the student had previously read; since this information was within two sentences of the think aloud comment I coded the knowledge source for this explanation as maintenance of an idea.

An example of retrieval of an idea as a knowledge source occurred during another student's interaction with the plants informational text. Near the very end, the text describes how the "flowers help the tree make acorns" and "the acorns grow fat during the spring and summer." After reading these two statements, the student predicted that the acorns would "drop" to the ground. The idea that the acorns drop to the ground after growing on the trees had been previously stated at the beginning of this text (see sentence three). Therefore, I coded the knowledge source for this prediction as retrieval of an idea.

After coding the knowledge source for each inference, I calculated a total percentage for each knowledge source used per text for each student and examined these percentages for patterns within and across texts. Finally, I examined the data to see what knowledge sources students relied upon to generate each type of inference.

Inaccurate ideas. Across all text interactions, I also noted if an idea statement was scientifically inaccurate. I considered students' idea statements to be scientifically inaccurate if they: 1) refuted or did not accurately reflect information that had been stated in the text and/or 2) did not correspond with current, widely accepted scientific concepts. For example, after reading about one of the observations regarding making sound with the ruler, one student predicted that "you will hear a lower sound when you push down harder." I coded this prediction as inaccurate because when you push the ruler down with more force one would hear a louder, not lower, sound. Another example occurred when a different student interacted with the plants data text. After reading about the pumpkins growing, this student elaborated on the text to talk about where the pumpkins come from, in this case stating that the pumpkin comes out of the sprouting leaves. This information was not stated in the text and would not be considered correct by scientists. Therefore, I coded this association as an inaccurate idea.

One of the primary goals was to determine how inaccurate ideas were implicated, if at all, in the relationships among students' strategy use, prior knowledge, and comprehension (e.g., do students who generate more inaccurate ideas tend to have more limited prior knowledge and lower comprehension scores?) To achieve this goal, for each student per text I calculated the percentage of idea statements that included inaccurate ideas. Then, I used correlations to examine how the percentage of inaccurate ideas relates to students' strategy use, prior knowledge and comprehension. Finally, I examined the data in more detail to determine what percentage of each comment type represented inaccurate ideas (e.g., what percentage of explanations are coded as inaccurate ideas for the sound informational text?) and used this information to determine where the inaccurate ideas originate most and least often. Overall, I found that there were no significant relationships between inaccurate ideas, students' prior knowledge, or strategy use, so information from this analysis is not featured or discussed in the results chapters.

Prior knowledge. My third and final research question addresses the relationships among students' prior knowledge, strategy use and comprehension. In order to answer this research question, I first designed a coding system for the prior knowledge interview responses and then examined the relationship between students' overall prior knowledge scores and their strategy use.

Each prior knowledge interview includes a series of open-ended questions addressing the major concepts for that topic at the elementary level (e.g., plant parts and functions, plant requirements and purpose, how sound is made, how sound changes pitch and volume). I coded each response on a three-point scale. A score of two meant that the response showed an *adequate understanding* of the key concept(s) identified and there were no misconceptions were present in the response. An adequate understanding means that students' responses accurately addressed all required components for a particular question. A score of one meant that the student's response showed a *developing understanding* of the key concept(s) identified; there might be one or more misconceptions present. A developing understanding means that the students' responses accurately addresses most, but not all, of the required components for a particular question. A score of zero meant that the student's response showed a *limited understanding of* the key concept(s), which means the response accurately addressed none or a minimal portion of the required components for a particular question or the student was unable to provide a response to the question posed. I calculated total scores for each student on both the sound and plants prior knowledge interviews.

These total scores represent students' mastery of the prior knowledge likely required to understand each text. As detailed below, some concepts (plant parts and their function; plant requirements and their role; how to change pitch; how to change volume) are more heavily weighted in the total score. I did this purposefully for various reasons. First, the plant texts in this study explicitly mention many plant parts, including the seeds, roots, stem, leaves, flowers, and fruit. In addition, although the texts do not directly identify plant requirements, students would need to draw upon these ideas in order to understand underlying mechanisms for plant growth. Since all of the individual plant parts and plant requirements are potential sources for students' inference generation, it made sense conceptually to count them separately in the coding scheme.

Likewise, both sound texts addressed concepts related to changing the pitch and volume of an object. Specifically, the texts discussed or shared observations regarding both how to make an object's pitch higher and lower and how to make an object's volume louder or softer. Since students might use each individual idea as a possible source for generating inferences, it seemed reasonable to weigh these two concepts (changing pitch and volume) more heavily in the total score. It is important to note that I did investigate weighting the prior knowledge scores so that each concept (e.g., plant identification, plant parts and functions, plant requirement and role, and plant's life cycle) contributed equally to the total score. The unweighted and weighted prior knowledge scores for plants ($r = .858$, $p < .01$) and sound ($r = .962$, $p < .01$) were significantly and positively correlated.

Sound. The sound prior knowledge interview questions addressed the following performance expectations: 1) knows about when sounds can be produced, 2) recognizes the role of vibration in the production of sound, 3) identifies the source of the vibration in the production of a given sound, 4) understands that volume of the sound can be made softer by decreasing the force used to vibrate the moving part and the sound is softer because the moving part is vibrating less air, 5) understands that the volume of the sound can be made louder by increasing the force used to vibrate the moving part and the sound is louder because the moving part is vibrating more air, 6) understands that the pitch can be made lower by decreasing how rapidly the vibrating part moves and the sound is lower because the vibrations are slower, and 7) understand that the pitch can be made higher by increasing how rapidly the vibrating part moves and the sound is lower because the vibrations are faster.

Scores on the sound prior knowledge assessment could range from zero to 14 points. Although the sound interview includes five questions, I counted two separate components for the last two questions. For question four, I coded the students' response for evidence of understanding how to make the sound louder and softer. In question five, I coded their responses for whether they understood how to make the sound higher and lower.

Plants. The plants prior knowledge interview questions addressed the following performance expectations: 1) identifies different types of plants and non-plants, 2) knows about the parts of a plant (roots, stem, leaves, flowers, seed, fruit), 3) understands the function of the parts of a plant, 4) identifies plants' requirements for growth (air, light, water, nutrients, space), 5) understands the role that different requirements play in plant growth and development, and 6) identifies the major stages in the life cycle of a plant (seed, plant, flower, fruit).

Scores for the plants prior knowledge assessment comprised a broader range than those for the corresponding sound assessment. I scored multiple components of

questions two and three; I coded each plant part and requirement the student identified as a separate unit. Thus, the coding scale scores for the plants prior knowledge assessment ranged from zero to 26 points. Tables 3.8 and 3.9 provide the interview questions, desired responses for each question, and coding criteria used to score each response in the sound and plants prior knowledge interviews.

Analysis. I trained a graduate student who is an experienced and knowledgeable elementary science instructor to score a random sample of students' prior knowledge responses for both topics (11 of the 84 students). I calculated a Kappa statistic to determine the measure of agreement between our scores. The Kappa statistic on these eleven prior knowledge interviews was 0.747, which is considered a good level of agreement (Altman, 1991). For each text, I examined correlations between students' prior knowledge scores and the overall number of idea statements, inferences, non-inferences, and particular comment types to ascertain whether students' prior knowledge is related to the type and frequency of strategies they made as they read each text.

Comprehension. The final research question also focuses on whether students' comprehension varies as a function of strategy use and/or prior knowledge. To answer this question, I began by developing a coding system for the comprehension questions and then analyzed the relationship between students' comprehension scores and these other variables.

Coding. After reading each text, each student answered six comprehension questions related to the ideas in that text. I individually scored each response as either adequate understanding (two points), developing understanding (one point), or limited understanding (zero points). To receive adequate understanding, responses had to be

Table 3.8. Prior Knowledge Interview Questions, Desired Responses, and Scoring Criteria for Sound Topic

Question	Desired Response	Scoring Criteria		
		Adequate Understanding (2 points)	Developing Understanding (1 point)	Limited Understanding (0 points)
Question 1: Is sound made in the following situations: person hitting a drum, watching a violin sitting on a table, birds flapping their wings, person bouncing a ball, rocking chair sitting still on floor? What are some other situations when sound would be made? Would not be made?	Sound is made in the following situations: person hitting a drum, birds flapping their wings, person bouncing a ball. Sound is not made in the following situations: watching a violin sitting on a table, rocking chair sitting still on the floor. Situations that involve movement of an object make sound.	All examples correctly identified.	Most examples (greater than 75%) correctly identified.	Few or no examples correctly identified.
Question 2: How is sound made? What do you need to make a sound?	Sound is produced when objects vibrate. When objects vibrate they move back and forth very quickly.	Explains the importance of vibrations and/or sound waves in making sound	Explains the importance of movement in making sound and/or identifies one or more ways that sound can be made (using different objects)	Does not identify how to make sound

Table 3.8 (cont'd).

Question	Desired Response	Scoring Criteria		
		Adequate Understanding (2 points)	Developing Understanding (1 point)	Limited Understanding (0 points)
Question 3: Can you make a sound using the rubber band box instrument? What part of the instrument makes the sound? Why does this part make the sound? How can you hear the sound?	The rubber band is making the sound because it is moving back and forth (vibrating) when I pluck it. I can hear the sound because the vibrations travel through the air into my ear.	Identifies part of instrument that makes sound, explains what causes the sound to be made, and explains how you hear the sound	Identifies part of instrument that makes sound and explains what causes the sound to be made	Does or does not identify part of the instrument that makes sound; does not explain what causes the sound to be made or how you hear the sound

Table 3.8 (cont'd).

Question	Desired Response	Scoring Criteria		
		Adequate Understanding (2 points)	Developing Understanding (1 point)	Limited Understanding (0 points)
Question 4: How can you change the *volume* of the sound of the rubber band box instrument? For each idea the student shares: How does that (e.g., plucking harder) change the sound (what you hear)? Why does the sound change in that way (e.g. get louder)?	You can make the volume softer by plucking the rubber band more gently. The sound is softer because the rubber band is vibrating less air (sound wave is smaller; not as much force on it; or not that much vibration). You can make the volume louder by plucking the rubber band harder. The sound is louder because the rubber band is vibrating more air (sound wave is bigger; more force on it; or have more vibrations).	Identifies volume change as louder or softer (e.g., soft), what you need to do to change the volume in that way (e.g., pluck the rubber band gently), and why the volume changes (e.g., because the rubber band does not vibrate as much air)	Response shows evidence of 2 of the 3 following concepts: identifies volume change as louder or softer, what you need to do to change the volume in that way, and why the volume changes	Identifies either how the volume can change OR what you need to do to change the volume in that way OR incorrect response

Table 3.8 (cont'd).

Question	Desired Response	Scoring Criteria		
		Adequate Understanding (2 points)	Developing Understanding (1 point)	Limited Understanding (0 points)
Question 5: How can you change the *pitch* of the sound of the rubber band box instrument? For each idea the student shares: How does that (e.g., using a thinner rubber band) change the sound (what you hear)? Why does the sound change in that way (e.g. higher pitch)?	You can make the pitch higher by making the rubber band tighter (using bigger box, thinner rubber band, or by pulling rubber band tighter). The sound is higher because the vibrations are faster. You can make the pitch lower by making the rubber band looser (use a smaller box) or using a thicker rubber band. The sound is lower because the vibrations are slower.	Identifies how the pitch can change (e.g., higher), what you need to do to change the pitch in that way (e.g., make rubber band tighter), and why the pitch changes (e.g., because the vibrations are faster)	Response shows evidence of 2 of the 3 following concepts: identifies how the pitch can change, what you need to do to change the pitch in that way, and why the pitch changes	Identifies only how the pitch can change OR what you need to do to change the pitch in that way OR incorrect response

Table 3.9. Prior Knowledge Interview Questions, Desired Responses, and Scoring Criteria for Plants Topic

Question	Desired Response	Scoring Criteria		
		Adequate Understanding (2 points)	Developing Understanding (1 point)	Limited Understanding (0 points)
Question 1: Are the following items plants: flower, tree, cow, dandelion, person? What are some other examples of plants? Non-plants?	Plants include: flower, tree, dandelion. Non-plants include: cow, person.	All examples correctly identified.	Most examples (greater than 75%) correctly identified.	Few or no examples correctly identified.
Question 2: What are the parts of a plant? For each plant part the student identifies: How does this part help the plant?	**Roots** – absorb moisture; provide water and nutrients to plant; help plant stay in ground **Stem** – support plant; provide water and nutrient to other parts of plant (e.g., leaves) **Leaves** – make food for the plant **Flowers/Petals** – make seeds; help pollinate plant (attract pollinators to aid fertilization) **Fruit** – protects seeds; helps disperse/scatter seeds **Seeds** – begins growing from a seed (baby plant)	Identifies plant part and at least one role	Identifies plant part	Does not identify plant part or its role

Table 3.9 (cont'd).

Question	Desired Response	Scoring Criteria		
		Adequate Understanding (2 points)	Developing Understanding (1 point)	Limited Understanding (0 points)
Question 3: What does a plant need to grow? For each plant requirement a student identifies: How does this item help the plant grow?	**Air/carbon dioxide/oxygen** – use carbon dioxide in air to make food for plant; use oxygen for respiration **Light** – use sunlight to make their own food **Water** – helps plant make and move nutrients **Nutrients/Fertilizer** – help plant parts be healthy (e.g., helps with cell division, flower and seed production, produce strong stem and roots) **Space** – so leaves can expand and make food for plant so roots are not crowded	Identifies plant requirement and at least one role	Identifies plant requirement	Does not identify plant requirement or its role
Question 4: How does a plant (e.g., apple tree) change over time? (e.g., How does it start? What happens next?)	Seed → Plant → Flower → Fruit	Correctly identifies all four stages in life cycle of plant in order	Identifies at least three stages in life cycle of plant (may or may not be in order)	Identifies two or less stages in life cycle of plant

accurate, complete, and free from misconceptions. I gave developing understanding for responses that were mostly complete and correct and limited understanding for inaccurate and/or incomplete responses.

For example, one of the questions for the sound informational task was, “How do you hear a beating drum from across the room?” To receive adequate understanding, students had to accurately describe the movement of the sound waves/vibrations and explain how the sound waves/vibrations travel through the air to our ears. Developing understanding would be given for any responses that included one of these components (e.g., “I think like waves come over the room.”) while limited understanding would be assigned for responses that did not address any of these components (e.g., “Cause sounds are louder and you hit them hard.”). Appendices L to O provide example student responses for adequate, developing, and limited understanding on each of the comprehension questions. I computed three individual scores for each student per text: 1) an overall score (ranging from zero to 12 points), 2) an explicit score (ranging from zero to six points), and 3) an implicit score (ranging from zero to six points).

Analysis. Similar to the prior knowledge responses, I trained a graduate student who is an experienced and knowledgeable elementary science instructor to score a random sample of students’ responses on the comprehension questions (11 of the 84 students). The Kappa statistic for these comprehension question responses was 0.743, which is also within the range for good agreement (Altman, 1991).

I examined the data to determine if there is a relationship between strategy use and students’ comprehension of the information in the text. Specifically, I explored whether students who generate more (less) inferences overall or more (less) of particular types of comments (e.g., explanations, association, predictions, paraphrases, etc.) tend to have higher (lower) comprehension question scores? I calculated correlations between students' overall, explicit and implicit comprehension scores on each text and the number of different types of comments they produced. I also examined the relationship between students' topic-specific prior knowledge and their comprehension using correlations.

Developing linear regression models. In the final step of the analysis, I used information gleaned from the above statistical analyses to develop a linear regression model to determine what factors predict students' comprehension for each text. For each text, I conducted a stepwise linear regression model using students' overall comprehension on each text as the outcome variable. In each step, I added variables related to students' comprehension as predictors in the model. Specifically, in step one, I used students' topic-specific prior knowledge scores as the first predictor. In the remaining steps, I added the three inference types (explanations, predictions, and associations) and paraphrases as predictors in the model.

In the next three chapters, I present the results from the analysis of students' text interactions and the relationship between these interactions and students' prior knowledge and comprehension. First, I provide detailed information to show that students' text interactions were dominated by inferences and paraphrases and that students used particular patterns of inferences for specific texts. Then, I report on the relationships between students' prior knowledge, strategy use, and comprehension and present findings to show that prior knowledge is an important factor related to both students' inference generation and their comprehension. Finally, I present one case study example to illustrate the patterns in the data.

Chapter 4: Strategies Third Graders Use to Comprehend Science Texts: The Predominance of Inferences and Paraphrases

If we want to help students comprehend particular types of science texts, we need to understand the strategies they use when reading these texts, what resources they draw upon, and how the strategies and resources they use impact their comprehension. This information will better position educators to build students' abilities to comprehend science informational and data texts. In this chapter I present results to illuminate the first part of this issue – what strategies students employ to understand science texts.

The literature review indicated that various factors are implicated in the relationship between students' strategy use and text comprehension. The idea that text genre is a critical feature impacting students' text processing and comprehension is a widely held belief supported in the literature. However, it remains to be seen how this relationship between text genre and students' strategy use plays out using two text genres important to the science discipline – informational texts and data texts – and across different science topics. It is important to note that when I framed this study, I defined text genre to refer to particular text types and I identified these text types by specific structural features. Although more nuanced models of text genre exist, when researchers design studies that compare students' interactions with different text genres, or types, they are most likely to focus on the difference in structural features to define each genre category. Also, the most common way of discussing and referring to literature in the elementary curriculum is by genre distinctions, which typically refer to different types of fictional and expository texts (e.g. realistic fiction, descriptive texts, how-to books, etc.). Therefore, in this study, I also decided to examine this dimension of genre in more depth

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and selected the particular science texts to do so. In this chapter, I present findings to show that students used particular strategies, mainly explanations, associations, predictions, and paraphrases, to comprehend these texts and that the patterns in students' text interactions are not neatly divided across either text type or topic. These findings suggest that we need to move beyond thinking about text genre as simply the structural features of the texts and move towards a more complex view of genre, which more thoroughly considers the nature of the science content that is represented in the texts to understand how students interact with and comprehend science texts.

Students' think aloud comments revealed a variety of different strategies, including different types of inferences, namely explanations, predictions, and associations, as well as other comment types (paraphrases, metacomments, personal connections, questions, visualizations, personification, and incomprehensible statements). Table 4.1 displays the means and standard deviations for the average number of each inference type students generated by text, while Table 4.2 displays the means and standard deviations for the average number of non-inferences students produced by text.

Table 4.1. Means (standard deviations) for Number of Inferences per Student by Text

Type of Think Aloud Comment	Sound – Informational[a]	Sound – Data[a]	Plants – Informational[a]	Plants – Data[a]	All Four Texts
Explanations	1.95 (2.02)	6.35 (5.15)	2.39 (2.52)	2.40 (2.80)	13.10 (10.02)
Predictions	3.36 (2.93)	2.92 (2.57)	5.11 (4.30)	3.11 (2.80)	14.49 (9.64)
Associations	7.35 (4.62)	2.79 (2.66)	5.00 (3.24)	5.00 (3.16)	20.13 (10.06)
Total Inferences	12.65 (7.02)	12.05 (6.92)	12.50 (6.87)	10.51 (5.96)	47.71 (23.23)

[a] n=84 for each text

Table 4.2. Means (standard deviations) for Number of Non-inferences per Student across Texts

Type of Think Aloud Comment	Sound – Informational[a]	Sound – Data[a]	Plants – Informational[a]	Plants – Data[a]	All Four Texts
Paraphrases	5.94 (4.81)	7.92 (5.06)	7.81 (5.51)	6.67 (5.46)	28.33 (18.54)
Metacomments	2.01 (3.18)	1.01 (2.31)	1.45 (2.57)	.87 (2.03)	5.36 (8.40)
Personal Connections	.38 (1.03)	.64 (2.54)	.51 (1.42)	.64 (2.54)	2.18 (6.01)
Questions	.29 (1.41)	.27 (1.26)	.40 (1.69)	.29 (1.06)	1.25 (4.94)
Visualizations	.07 (.40)	.20 (1.38)	.25 (1.76)	.35 (1.73)	.89 (4.39)
Personification	.00 (.000)	.00 (.000)	.04 (.24)	.05 (.27)	.08 (.35)
Incomprehensible Statements	.32 (.62)	.33 (.68)	.42 (.84)	.27 (.61)	1.35 (1.49)
Total Non-Inferences	9.02 (5.10)	10.38 (5.15)	10.88 (5.86)	9.13 (5.46)	39.42 (18.12)

[a] n=84 for each text

These tables reveal that on average students generated paraphrases (M=28.33, SD=18.54), or reproductions of the text, most frequently, followed by the three inferences types – associations (M=20.13, SD=10.06), predictions (M=14.49, SD=9.64), and explanations (M=13.10, SD=10.02). On average students were less likely to state metacomments, personal connections, questions, visualizations, or personification statements while thinking aloud. This predominance of paraphrases and inferences

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occurred across all four texts; however, a closer look reveals that paraphrases and particular inference types were more (or less) likely to be used depending on the text type and/or topic. In addition, differences in the content of the inferences (e.g., what students focus on when generating explanation) can be seen when looking at actual examples students produced for each text. These differences support the argument that we need to move towards a more complex view of text genre to understand student-text interactions.

I now turn to a look at patterns in how students employed inferences and paraphrases while reading the informational and data texts. To show how students' strategy use goes beyond genre classifications (in this case conceived as differences in structural text features), I will describe the frequency of each comment type in the data across the four texts, report any significant differences by text and topic, and provide examples from students' think aloud comments. Table 4.3 summarizes the ANOVA results and marks significant main effects (topic and type) and interaction effects (topic by text) for the different types of inferences and paraphrases.

Table 4.3. F-Test Values for 2 X 2 Repeated Measures ANOVA Main Effects and Interaction Effects for Inferences and Paraphrases

Type of Think Aloud Comment	Topic (main effect)	Type (main effect)	Topic by Type (interaction effect)
Explanations	$F(1, 76) = 40.419$***	$F(1, 76) = 43.338$***	$F(1, 76) = 73.883$***
Predictions	$F(1, 76) = 13.095$**	$F(1, 76) = 13.710$***	$F(1, 76) = 12.786$***
Associations	$F(1, 76) = .982$	$F(1, 76) = 61.350$***	$F(1, 76) = 50.505$***
Paraphrases	$F(1, 76) = .379$	$F(1, 76) = 1.786$	$F(1, 76) = 40.562$***

*$p < .05$; **$p < .01$; ***$p < .001$

Explanations

Students provided a variety of explanations in order to detail reasons for the current state of objects or events. Beyond this difference, though, we also see variation in the kinds of explanations students made across these texts. Overwhelmingly, the explanations that students did generate tended to be reasons for particular observations. Only a small portion of these explanations focused on underlying reasons for data patterns; these types of explanations were mainly found in students' interactions with the sound informational text.

Quantitative Results. Across all four texts students generated an average of 13.10 total explanations (SD=10.02) in their think aloud comments. The majority of these explanations occurred during students' interaction with the data text on sound (M=6.35, SD=5.15). For the other texts, students provided an average of approximately two explanations per text. The number of explanations ranged from a minimum of zero to a maximum of 20 explanations per text with a median of 12.00 explanations.

For number of explanations generated, the main effect for topic, the main effect for text type, and the interaction were all significant. The main effect of topic is such that students generated a significantly larger number of explanations when interacting with the sound (M=4.15) versus the plants texts (M=2.40). In addition, the main effect of text type reflects that the mean number of explanations for the data texts (M=4.38) was significantly greater than the mean number of explanations for the informational texts (M=2.17). Upon closer inspection, it appears that the effect of text type is being driven by the sound topic.

Post hoc paired t-tests showed significant differences between the mean number of explanations for the sound data text (M=6.35) and: 1) the sound informational text (M=1.95), [t(83) = 9.222, p < .001], 2) the plants informational text (M=2.39), [t(83) = 7.753, p < .001], and 3) the plants data text (M=2.40), [t(83) = 8.178, p < .001]. On average, students generated a significantly greater number of explanations in their think aloud comments for the sound data text compared to the other three texts. The effect size for the interaction was strong (η_p^2 = .493), meaning 49.3% of the variance in the number of explanations students produce can be attributed to the interaction of topic and text type when controlling for other factors. Figure 4.1 shows the relationship between number of explanations by text type and topic.

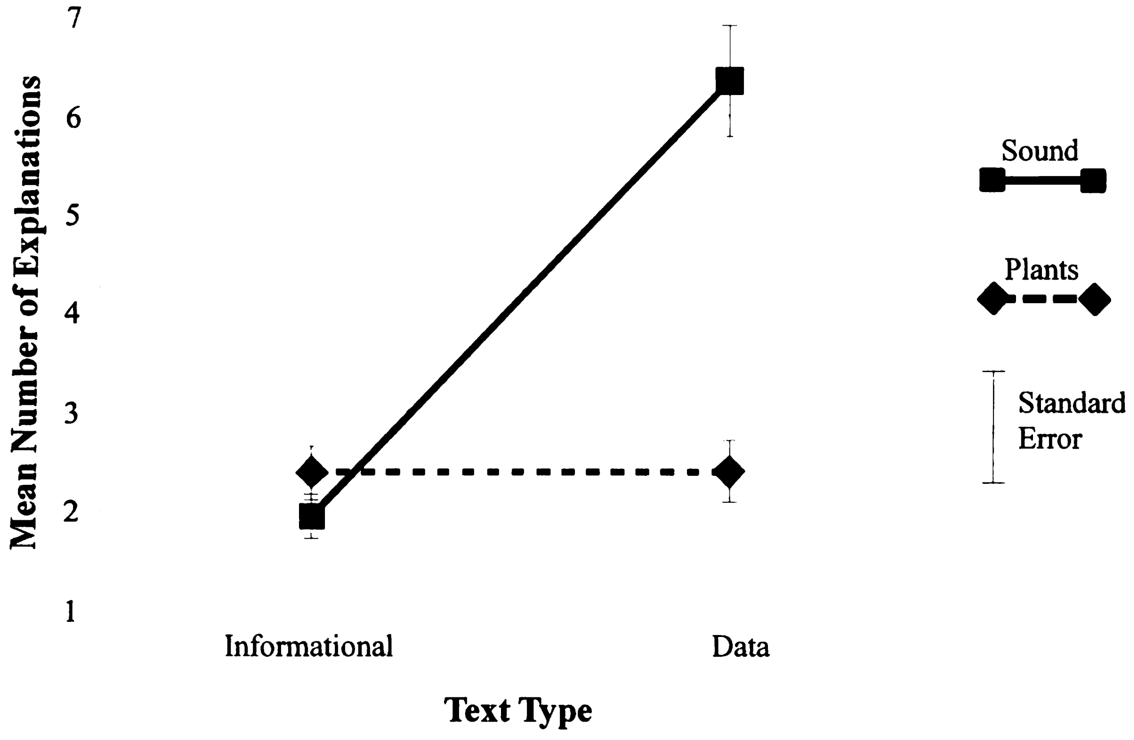


Figure 4.1. Mean (and standard error of) number of explanations by text type and topic

This result means that text type alone cannot account for students' use of explanations to comprehend texts. In other words, it is not that students generate more explanations in response to data texts in general; instead, it is the sound data text specifically – a data text that has multiple observations detailing how sound can be made using multiple objects and was accompanied by real world tools for students to access during reading. This finding supports the contention that we need to go beyond genre distinctions in order to understand how students interact with science texts.

Qualitative Illustrations. When interacting with the sound data text, it was common for students to explain why the different parts of the sound systems were moving and why sound was produced from each object. Students commented, for example, that "the ruler shakes from side to side when you pluck it" and the thumb plucker makes a sound because "it [popsicle stick] is going up and down…hitting the top and bottom pieces of wood." Both comments focused on what students could actually see to explain these observations and did not address model-based reasons for these observations (e.g., role of vibrations or sound waves). These types of comments accounted for the majority of explanations students produced while reading the sound data text. In a few cases, students tried to provide reasons for why the pitch or volume of particular objects changed. For example, one student explained that you hear a loud sound when you push down hard on the popsicle stick "because it makes a bigger sound wave," while you hear a soft sound "because you didn't use as much force." A different student reasoned that the thumb plucker produced a higher sound because "it has a little room to vibrate," and a lower sound because "it has a lot of room to vibrate."

Although students did not generate as many explanations for the sound informational text, the explanations they did produce were qualitatively different. This qualitative difference focused on whether or not the ideas addressed the underlying invisible mechanisms for the scientific phenomena. When responding to ideas in the sound informational text, almost all the explanations students produced accounted for why sounds have different pitches and volumes. For example, students gave many reasons for why the lion's roar is low: it is a bigger animal; it has a smaller neck; it moves slower than other animals; its voice box is low; and the vibrations in its throat move slowly. Students also tried to explain why loud sounds vibrate more air: the sound wave is bigger; loud sounds take up more room; and the sound wave travels fast. Many of these explanations address patterns in the data and focus on mechanisms, or model-based reasons, for these patterns.

Students also generated explanations when interacting with the plants texts; this occurred less frequently than with the sound data text and at about the same frequency as with the sound informational text. Students' explanations in response to the ideas stated in the plants texts also tried to elucidate reasons for current actions or events and these explanations focused on reasons for various observations, similar to what we saw with the sound data text. Most explanations for the plants texts addressed why certain plant parts changed. For example, students provided reasons why the acorn cracked open, such as "it hits the ground," "the leaf is pushing the acorn open," "a lot of people have stepped on them," and "the squirrel comes and cracks it open with their teeth." Likewise, students talked about why the pumpkin seed began to break apart on day seven: "because the plant is starting to sprout up;" "cause the roots are in;" and "because the stem is coming up for the pumpkin." In these responses, it is much harder to see any evidence of an explicit model. Although less common, some students described conditions needed for plant growth: "cause it rained and the sun came out;" "needs lot of years to get all the sunshine and water that it needs;" and "because it had water and sunlight." Students also mentioned various reasons for why particular plant parts grew, such as explaining that the roots grew longer "because they need a lot more nutrients…and water" and "they can suck in water for the plant;" the stem became thicker "because it needs more room for the water to go through;" and the leaves got bigger so "they can grab more sunlight." As these examples show, differences in the types of explanations students made across the four texts suggest that what the science content is and how it is represented is related to students' strategy use.

Predictions

Another typical response to the text ideas was to make predictions about possible events or occurrences that were or were not later confirmed by the text. Predictions are referred to as forward inferences because they consider next steps in a process or event. Similar to explanations, the analysis shows differences in students' use of predictions across text types and topics.

Quantitative Results. Overall students made an average of 14.49 (SD=9.64) total predictions across all four texts. On average, the plants informational text prompted the greatest number of predictions (M=5.11, SD=4.30); in comparison students generated approximately three predictions per text while interacting with the other three texts. Some students made no predictions while one student made 21 predictions when interacting with the plants informational text; the median number of predictions produced per text was 14.00.

For number of predictions generated, the main effect for topic, the main effect for text type, and the interaction were all significant. The number of predictions students produce depends upon both text type and topic. Specifically, students produced a greater number of predictions when interacting with the plants texts (M=4.11) as compared to the sound texts (M=3.14). Also, students generated significantly more predictions when reading the informational texts (M=4.23) as compared to the data texts (M=3.01) and this pattern was evident within each topic. The interaction effect shows that the type effect is stronger in the plants texts. That is, for both topics students generated more predictions for the informational text, but this difference was much more pronounced for the plants texts. Figure 4.2 displays a graphical representation of the relationship between text type and topic for mean number of predictions. These findings reinforce the argument that text type, or genre, is not the defining characteristic to consider when thinking about differences in strategy use.

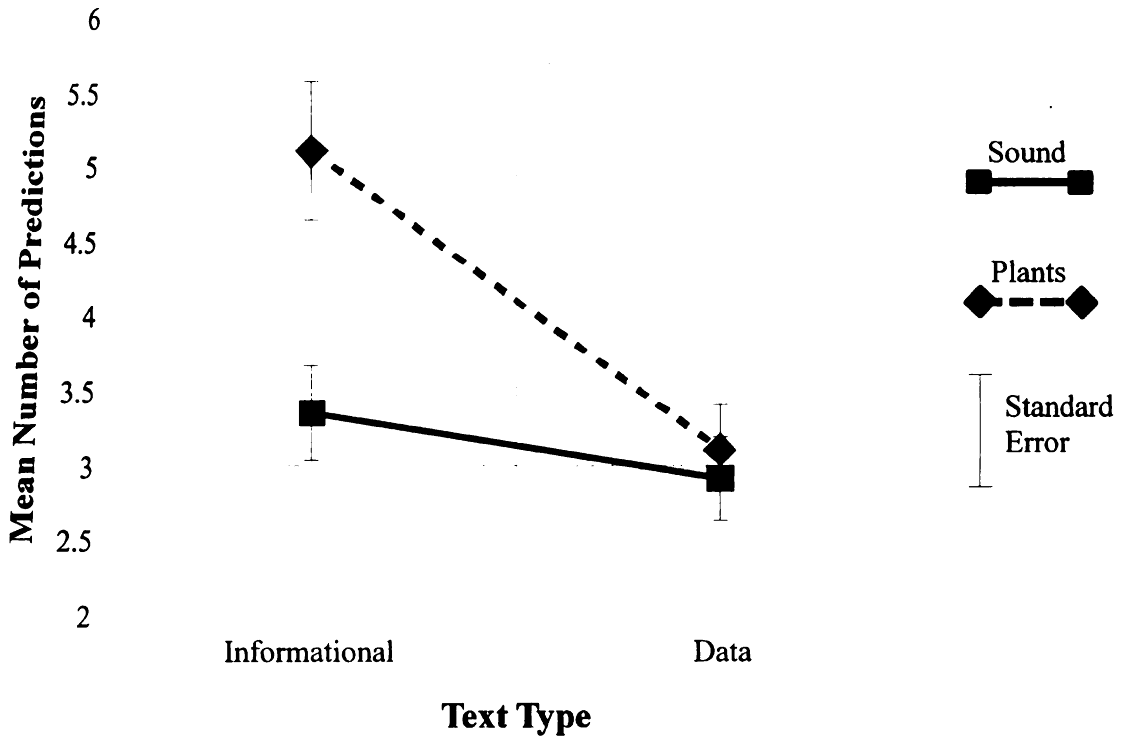


Figure 4.2. Mean (and standard error of) number of predictions by text type and topic

Qualitative Illustrations. A majority of the predictions associated with both texts about plants were statements detailing the next step(s) in the growth process. One student predicted that after growing on the oak tree branches the acorns would "fall off and…start growing a new tree" and once the acorn cracks open "it gets into the ground and makes an oak tree." Some students mentioned how the roots and stem will grow bigger, the leaves would fall off the oak tree branches, and the flower would turn into an acorn or pumpkin, all ideas that were later confirmed by these texts. Occasionally students would make predictions about potential uses or activities for the pumpkin - such as "waiting for someone to pick it" and getting "ready for Halloween" to "carve faces into it" - and acorn (e.g., "somebody would pick it up and plant it."; "squirrels will eat them"), although these predictions were not substantiated by the text. It is not surprising that when students made predictions for the plants texts, they zeroed in on the next stage in the plant's life cycle. When the science content is organized in a temporal sequence, students seem to recognize this pattern and make predictions detailing the next steps in the process

When students made predictions while reading the sound texts, they tended to consider what would happen in related situations. For the sound data text, students' predictions focused mainly on the implied patterns in the data, relating the observations about how one could manipulate objects to ideas about how to change their pitch and volume. For example, after reading about how pushing down hard on the thumb plucker creates a loud sound, one student predicted that "when you push not very hard it makes a like really, really soft sound." Similarly, following the observation about how pushing down on a long piece of the ruler creates a low sound, another student anticipated that if you "make the ruler shorter off the table it makes a...higher pitch." Similarly, the sound informational text stated that "big sound waves make louder sounds;" this statement prompted one student to conjecture that "smaller sound waves make littler sounds." Likewise, another student predicted that "if it goes like really fast then it'll make a higher sound" after reading that "slow vibrations make low pitched sounds." In addition, students would make predictions about how fast or slow objects would vibrate, depending on the type of sound being produced (e.g., the long ruler would vibrate faster when making a low sound), although these types of predictions were less common across the data set. When the text provides multiple observations of similar phenomena, students make predictions that show they are considering what will happen in related situations. Moreover, when reading the sound informational text, sometimes students made predictions about where the sound wave goes (e.g., "in your ear") and what it does (e.g., "hits your ear drum," "gives a message to your brain," "makes noise"). In a few instances, students stated their expectations about how a sound wave would be created and how one would hear sound when the objects moved.

Associations

Associations, or elaborations of text ideas, included: 1) providing examples or comparisons, 2) specifying additional features, properties, or functions of objects, 3) stating generalizations for data patterns, and 4) detailing additional procedural, temporal, or spatial information about events and objects.

Quantitative Results. Compared to explanations and predictions, associations (M=20.13, SD=10.06) were featured more prominently in students' think aloud comments across all four texts. On average students generated 7.35 (SD=4.62) associations for the sound informational text, 2.79 (SD=2.66) for the sound data text, 5.00 (SD=3.24) for the plants informational text, and 5.00 (SD=3.16) for the plants data text. Overall, the number of associations made by a student in response to any one text ranged from a minimum of zero to a maximum of 28, with a median of 6.50 associations generated per text.

For number of associations generated, the main effect for topic was not significant, but the main effect for text type and the interaction were both significant. Students generated significantly more associations when interacting with the informational texts (M=6.17) as compared to the data texts (M=3.89). Post hoc paired t-tests showed that there was no significant difference in the mean number of associations for the plants texts, $t(83) = .000$, $p = 1.000$, but there was a significant difference in the mean number of associations for the sound texts, $t(83) = 9.434$, $p < .001$. The effect size for topic by type is strong ($\eta_p^2 = .399$), which indicates that 39.9% of the variance in the number of associations can be accounted for by the interaction of these two variables excluding the other factors. Figure 4.3 shows a graph detailing the mean number of associations by text type and topic.

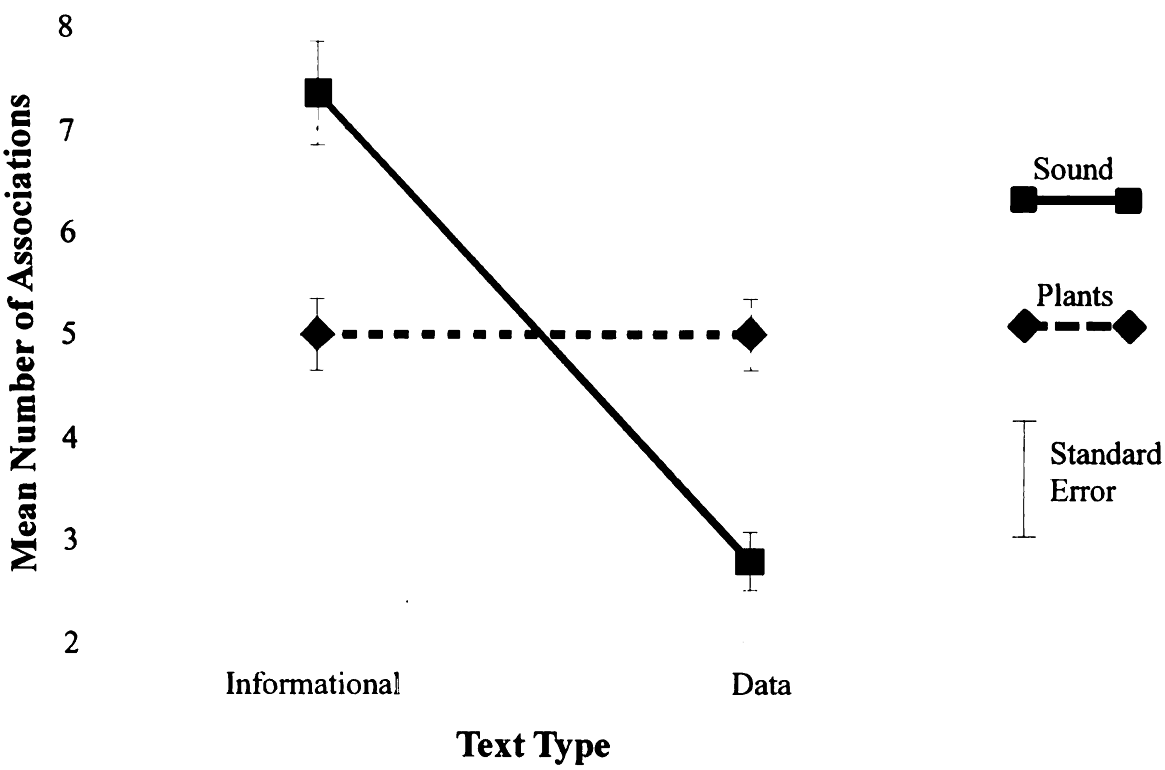


Figure 4.3. Mean (and standard error of) number of associations by text type and topic

This analysis shows students' generation of associations varies with text genre, but only for one topic (sound), suggesting that it is not necessarily the difference in text type that drives the variability in association generation, but that topic also plays a role. When we look more closely at the actual texts, we see that both plants texts describe a visible process – how a particular plant grows. In comparison the sound texts are much different from each other in that the sound data text presents concrete, tangible observations of three sound systems, while the sound informational text outlines explicit and implicit data patterns and explanations, which are more abstract in nature.

Qualitative Illustrations. On average students generated the greatest number of associations when reading the informational text about sound, the text that is most abstract in nature. They provided examples of different volumes (e.g., "high," "low," "super soft," and "super loud") as well as noted different ways to make sound, such as using an instrument (e.g., drum, flute, or guitar), tapping your feet, yelling, and using a radio. In addition, when responding to this text, students talked about what you need to make sound (e.g., air) and hear it (e.g., ears, ear drum); features of your ear (e.g., "shaped like a funnel") and particular sound waves (e.g., big sound waves being "heavier"); what different pitches sound like (e.g., low pitched sounds are deeper); how the vibrations move (e.g. "the vibrations are doing the domino thing"); and features of different instruments (e.g., "the drum is hollow").

Students made similar types of associations when interpreting another student's observations about what he saw, heard, and felt when making sound using three different objects, although on average students tended to make the fewest number of associations in response to the sound dàta text. One common pattern in students' associations for this text was the use of examples or comparisons related to the observations. For example, students shared how the thumb plucker "reminds me of a teeter-totter," talked about how playing the rubber band strummer was similar to plucking the strings on a guitar, and compared the movement of the ruler to a diving board moving up and down. Sometimes they even made comparisons between the three objects in the data chart, for instance, commenting how the ruler vibrates "just like the cup and thumb plucker." Students also provided additional information about features of the objects or different sounds produced, such as stating that the rubber band moves fast, the vibrations move up and down, and a low pitch makes a deep sound.

On average students produced an equivalent number of associations for both texts about plants. In general, the types of associations made across these texts were similar. One type of association found frequently in these texts (and rarely noted in the think aloud comments for the sound texts) related to the function of different objects, which was not surprising considering that this prior knowledge was predicted to be important for understanding the plants texts. In most cases, students commented on the functions of the roots, stating that "the roots…give a leaf water," the "shoot sucks up water from the ground," and the "roots get nutrients and water from the ground." Occasionally they mentioned the purpose of other important components (e.g., "the water and sunlight helping this plant get bigger and stronger").

It was also common for students to comment on the particular stage of growth for the oak tree or pumpkin plant (e.g., "it's a like a beginning of a regular tree" or "it's almost fully grown") or to describe what was happening to each plant at a particular point in time based on the current observations or ideas read (e.g., "it's growing and expanding" or "so that means it's growing even more"). Less frequently, students would specify particular features of plant parts, for example, commenting how the tree has bark and is tall, "the acorn has a big shell" and is "not that heavy," the "pumpkin's stems are really pointy and…has thorns on it," and the pumpkin is green first and then turns orange. On a few occasions, students made generalizations about what happens to plants as they grow (e.g., "that's what most plants would do" in regards to a stem growing out of the seed; "that's what mostly every plant does when it starts to grow" in response to the idea that roots grow into the ground).

Paraphrases

As described in chapter three, paraphrases are reproductions or restatements of key ideas or phrases in the text. Paraphrases were the most frequent type of think aloud comment produced across the data set.

Quantitative Results. Students averaged a total of 28.33 paraphrases (SD=18.54) and a median number of 26 paraphrases across all four texts. Means for paraphrases on individual texts averaged from 5.94 paraphrases (SD=4.81) for the sound informational text to 7.92 paraphrases (SD=5.06) for the sound data text, with the average number of paraphrases for the plants texts falling in between. Total number of paraphrases per text ranged from zero, which occurred for 26 text interactions, to 19, which three students made while responding to the plants informational text.

For number of paraphrases generated, the main effect for topic and the main effect for text type were not significant; however, the interaction was significant. The mean number of paraphrases for the sound texts (M=6.93) versus the plants text (M=7.124) and the informational texts (M=6.88) versus the data texts (M=7.29) were not significantly different. However, the pattern in the number of paraphrases by topic is different across text type. For the sound topic students generated more paraphrases for the data text (M=7.92) than for the informational text (M=5.94), while for the plants topic this pattern is reversed: students made more paraphrases for the informational text (M=7.81) than the data text (M=6.67). Post hoc paired t-tests indicated that the differences in the number of paraphrases within topics [for plants, $t(83) = 2.962$, $p < .01$, and for sound, $t(83) = -4.717$, $p < .001$] were significantly different. The effect size for topic by text was strong (η_p^2 =.348) indicating that 34.8% of the variance in the mean number of paraphrases students produced can be attributed to this interaction when controlling for other factors. Figure 4.4 shows the interaction effect by text type and topic for mean number of paraphrases.

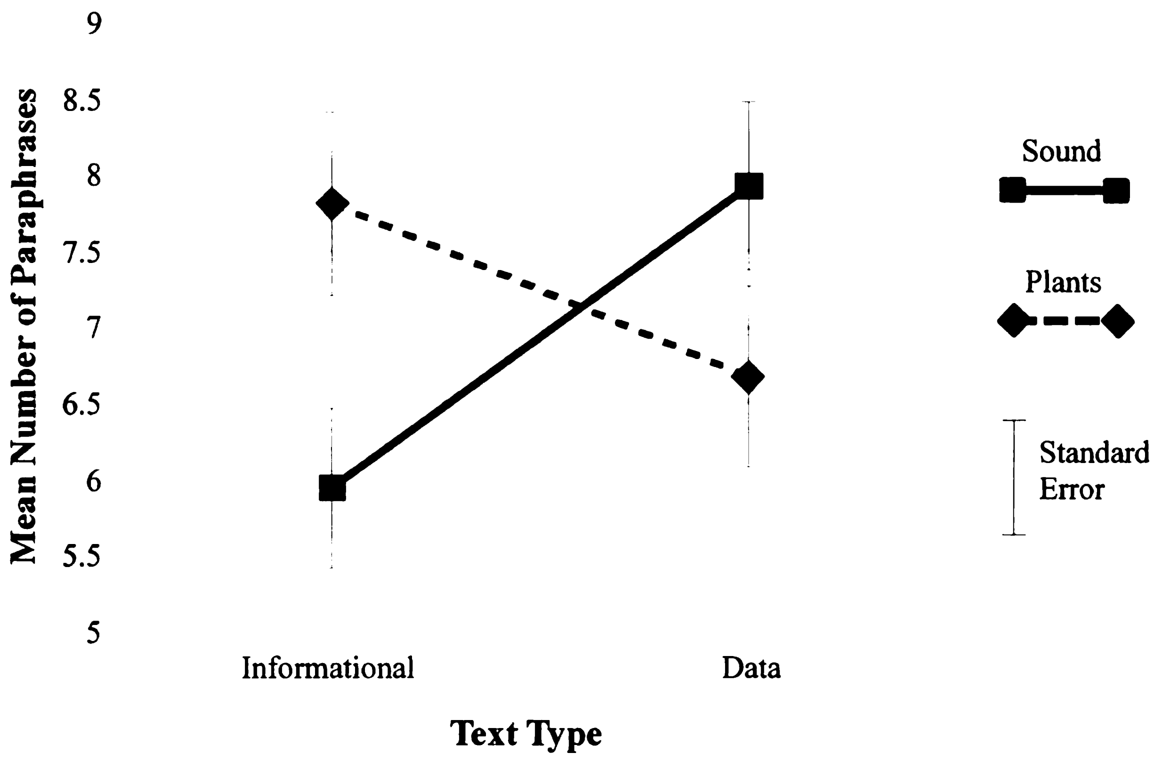


Figure 4.4. Mean (and standard error of) number of paraphrases by text type and topic

Qualitative Illustrations. In some cases, students would repeat the exact same sentence (or part of a sentence) they just read as their think aloud comment. I refer to these paraphrases as replicas because the student repeats the text he or she just read verbatim. In other cases, students would rephrase the idea using their words while maintaining the essential meaning of the text idea. I refer to these types of paraphrases as restatements. Table 4.4 provides some examples of paraphrases from students' think aloud comments.

Table 4.4. Examples of Paraphrases from Students' Think Aloud Comments

Written Text	Think Aloud Comment (Paraphrase)	Text Type	Paraphrase Type
You hear sound when the wave enters your ear.	The wave enters your ear.	Sound – Informational	Replica
When I pluck the short popsicle stick I hear a high sound.	When you pluck the small stick it makes a high pitch sound.	Sound – Data	Replica
I hear the ruler slapping the table.	And just, how can I put this, it like hit the table.	Sound – Data	Restatement
Acorns drop on the ground in the spring.	They drop on the ground in the spring.	Plants – Informational	Replica
Acorns grow fat during the spring and summer.	They start to get bigger.	Plants – Informational	Restatement
There are two leaves on the plant and the roots have grown much bigger.	It grew and grew until it got into until it got bigger.	Plants – Data	Restatement

The analysis of the number of paraphrases by text type and topic adds more support to the idea that understanding what students do with these texts requires a look at other factors besides just text genre. Here we see that knowing both text type and topic can help us explain a good amount of the variance in the number of paraphrases students generated. It is important to note that for all four texts we see a predominance of paraphrases used by students. One possibility is that students use paraphrases to help them secure the text content in their short term working memory, which enables them to draw upon the ideas for later use.

Summary

Overall findings show that both text type and topic are important factors for predicting the number of different types of inferences and paraphrases students generated when interacting with these four texts. Students generated the greatest number of explanations for the sound data text; produced a significantly greater number of predictions for the informational texts, with this difference being most prominent for the plants texts; provided significantly more associations when reading the informational texts, although this last relationship was being driven by the sound informational text; and produced a greater number of paraphrases for the sound data text and plants informational texts. In addition, the findings for the overall number of explanations, predictions, associations, and paraphrases students generated did not vary with gender or condition assignment overall. Taken as a whole, these findings suggest that we need to go beyond differences in just the structural features of genre to help understand how students interact with informational and data science texts. Patterns in students' text interactions are not consistent between topics and this suggests that specific features related to the topic, specifically how the science content is represented, also might be important for understanding these results. In the next chapter, I turn my attention to the second part of the problem – determining what resources students have at their disposal and how they use these resources to generate inferences and comprehend these texts. Then, I present results to show ways in which students' prior knowledge and strategy use relate to their comprehension.

Chapter 5: Prior Knowledge as a Critical Component of Inference Generation and Text Comprehension

Science texts, such as the ones in this study, are one potential vehicle for developing students' conceptual understanding and fostering their scientific literacy. However, research has shown that comprehending science texts can be a complex and arduous task. One assumption, widely supported in the literature, is that prior knowledge is strongly implicated in this relationship; that is, prior knowledge supports students' comprehension of texts. Another assumption is that inferences play an important role in creating valid, coherent understandings of these texts. The purpose of this chapter is to examine these assumptions in light of findings from this study. In doing so, I illuminate four separate, but related, patterns in the data: 1) students have an abundance of topic-specific prior knowledge at their disposal, and the majority of the conceptual knowledge they possess is about their experiences and observations of real-world phenomena; 2) they draw upon their prior knowledge extensively to generate inferences; 3) their prior knowledge is related to their text comprehension; and 4) only one inference type (explanations) is related to higher scores on students' text comprehension after taking prior knowledge into account.

Students' Knowledge of Sound and Plants: Frequent Use of Real-World Experiences and Observations

Approximately a week or more before asking students to read and respond to the four texts in this study, I conducted prior knowledge interviews with each student to ascertain his or her understanding of scientific concepts related to sound and plants. As detailed in the methods chapter, I scored students' responses to each question on a two-point scale (e.g., adequate understanding, developing understanding, and limited understanding). I wanted to know what knowledge and experiences students had at their disposal prior to reading these texts and how they used this knowledge when reading and comprehending the texts. I begin by answering the first part of this question. Findings revealed that the majority of students had a developing understanding of many concepts related to each topic. Across both topics students were more likely to identify various experiences or observations of tangible, real-world phenomena related to the topic and less likely to know about or to fully understand the underlying mechanisms that explain these observations.

Sound. The sound prior knowledge interview consisted of five questions, which covered multiple concepts about this topic. Two questions, the ones about volume and pitch, each had two components. Since I coded each question/component separately on a two point scale, final scores on the sound prior knowledge assessment could range from zero to 14 points. Table 5.1 provides the means, standard deviations, minimum, maximum, and median for the individual sound concepts assessed and the overall prior knowledge sound score.

On average, out of 14 possible points, students had a mean score of 6.26 (SD=2.18) on the sound prior knowledge interview. Students' total scores ranged from a low of two points, which was obtained by three different students, to a high of 13 points, garnered by one student. The median score for the sound prior knowledge was 6.00, which is close to the mean.

Table 5.1. Descriptive Statistics for Students' Responses to Sound Prior Knowledge Interview by Question and Performance Expectation

Question	Performance Expectation	M	SD	Min	Max	Median
Question 1: Is sound made in the following situations: person hitting a drum, watching a violin sitting on a table, birds flapping their wings, person bouncing a ball, rocking chair sitting still on floor? What are some other situations when sound would be made? Would not be made?	Identify situations when sound is and is not made	1.71	.45	1	2	2.00
Question 2: How is sound made? What do you need to make a sound?	Explain how sound is made	1.55	.57	0	2	2.00
Question 3: Can you make a sound using the rubber band box instrument? What part of the instrument makes the sound? Why does that part make sound? How can you hear the sound?	Identify part of instrument that makes sound and explain how you hear sound	1.40	.58	0	2	1.00

Table 5.1 (cont'd).

Question	Performance Expectation	M	SD	Min	Max	Median
Question 4: How can you change the *volume* of the sound of the rubber band box instrument? For each idea the student shares: How does that (e.g., plucking harder) change the sound (what you hear)? Why does the sound change in that way (e.g. get louder)?	Identify and explain how to change the volume – softer	.38	.66	0	2	.00
	Identify and explain how to change the volume – louder	.50	.75	0	2	.00
Question 5: How can you change the *pitch* of the sound of the rubber band box instrument? For each idea the student shares: How does that (e.g., using a thinner rubber band) change the sound (what you hear)? Why does the sound change in that way (e.g. higher pitch)?	Identify and explain how to change the pitch – higher	.33	.59	0	2	.00
	Identify and explain how to change the pitch – lower	.38	.58	0	2	.00
Totals		6.26	2.18	2	13	6.00

The first question addressed students' ability to identify situations when sound is and is not made. Of the 84 students, 60 students correctly identified all examples, while 24 students identified most examples correctly. The most common errors involved stating that a sound would not be made when birds flap their wings (e.g., because the bird is small) or when bouncing certain types of ball (e.g., "you would probably not hear the sound with a small ball…or bouncy ball"). Students provided multiple examples of other situations in which sound would be made, such as "when you talk," "when you're playing music," "tapping your fingers," a "pencil falling on the floor," "a wolf howling," "closing the door," and "when water rushes up the beach." Likewise, students identified numerous instances when sound would not be made including "when you are sitting and not moving or talking," "a toy sitting on the floor," "a bug or a cat just lying down," and "reading silently." The former examples all involved motion of some object(s) while the latter examples required the absence of movement. This idea – that sound is produced when an object moves – is implicit in the examples the students provided.

The second question asked students to explain how sound is made and to describe what is needed to make sound. The majority of students (49 of 84) mentioned the importance of vibrations, or sound waves, in making sound. For example, one student stated that "sound is made by vibrations that go to your ear that you can hear" while another student talked about how when a person's hitting a drum "there's vibrations…there's movement in the air that makes it so you can hear stuff...it goes into your ear and…your ear drum." A third student commented:

> Well, because when things sometimes hit together they make sound and the vibrations are made. Like when you pluck a string on a guitar. When something isn't doing anything it doesn't make sound. There has to be a movement for the sound to actually be heard.

Thirty students did not explicitly mention that sound is caused by vibrations, but instead either mentioned the importance of movement for making sound and/or identified various ways that sound can be made using different objects. These responses, coded as developing understanding, provided little indication that students understood the role that vibrations play in making sound. For example, one student talked about how "sound is made by how you move…like if you're hitting a drum…or stomping on the floor." Only three students were unable to provide examples of how to make sound using different objects and received a code of limited understanding for their response to this question.

During the next part of the interview, I used a rubber band box instrument (two rubber bands placed around an open shoe box) and asked students to make sound with the instrument, identify what part of the instrument makes the sound, and explain why and how you hear the sound. Thirty-eight students showed adequate understanding of this concept by accurately detailing all three components in their response. For example, one student said "because it [rubber band] moves and makes vibrations and it [vibrations] hits the walls and then it comes out and goes in your ears." This student clearly identified the part of the instrument making the sound, what caused it to do so, and described how you are able to hear the sound. Forty-two students were able to identify the part that produces the sound as well as explain what causes the sound to be made. For example, one student said:

> I think the rubber band does because you move it and it wiggles. Because you're touching it. When you're just touching it, it doesn't move. But when it moves, it makes a sound.

When asked about how you hear that sound, the same student responded that he was unsure. Four students were able to identify the rubber bands as the part of the instrument that makes the sound but did not explain why or how you hear the sound.

In the last two parts of the interview I asked students to discuss how they could change the volume and the pitch of the rubber band box instrument. I share findings related to students' understanding of volume first. The majority of students were unable to correctly identify how to make the volume softer (60 of the 84 students) or louder (55 of the 84 students). Approximately 16 of the 84 students could successfully identify how to change the volume in these two ways but not explain why the volume changed. These students talked about how you could play it gentler or "a little bit" to make a softer sound or how you could "pull it further" or "pluck it hard" to make a louder sound. However, only a small portion of the sample (eight students for softer and 13 students for louder) could also explain why the volume changes. For example, when describing how to make the sound louder one student said you could "pull it [the rubber band] harder" causing it to be louder and "vibrate bigger." Likewise, another student commented that "you could press on it lighter and it makes a quieter noise because you're not putting as much pressure on the rubber band."

The results for students' understanding of pitch followed a similar pattern: most students had a limited understanding of how to change the pitch of the rubber band box instrument to be higher (61 of the 84 students) or lower (56 of the 84 students). Some students (18 students for higher and 24 students for lower) had a partial understanding of these concepts while only a few (five students for higher and four students for lower) revealed an adequate understanding of these concepts. To make the sound higher, students mentioned various ideas such as using a thinner rubber band, making the rubber band tighter by using a bigger box, or manually stretching it out. Ideas shared about how to make the sound lower included loosening the rubber band by using a smaller box or using a thicker rubber band. Reasons offered for why the pitched changed in these ways were scarce, but one student did mention that a higher sound is created because "it's vibrating closer together" while another student talked about how a lower sound was made because "it has more room to vibrate."

Students' responses to these last three questions show their difficulty in explaining the underlying mechanistic reasons for observations and patterns. Findings show that students were more knowledgeable regarding concepts that could be observed (e.g., hear sound when you pluck the rubber band and it shakes; a louder sound is produced when you pluck the rubber band harder; a higher sound is made when you use a thinner rubber band). Students struggled to correctly explain the model-based reasons for these observations (e.g., you hear the sound when sound waves travel through the air to your ear; louder sounds vibrate more air; higher sounds are created by faster vibrations). We see the same pattern across students' responses to the plants questions.

Plants. The plants prior knowledge interview included four main parts; however, two parts – those about plant parts and plant requirements – involved multiple components. Students could receive credit for discussing six different plant parts and five different plant requirements. As for the sound concepts, I scored students' responses to each plant question/component on a two-point scale (adequate understanding, developing understanding, and limited understanding). Therefore, the scores for the

Table 5.2. Descriptive Statistics for Students' Responses to Plants Prior Knowledge Interview by Question and Performance Expectation

Question	Performance Expectation	M	SD	Min	Max	Median
Question 1: Are the following items plants: flower, tree, cow, dandelion, person? What are some other examples of plants? Non-plants?	Identify examples of plants and non-plants	1.72	.48	0	2	2.00
Question 2: What are the parts of a plant? For each plant part the student identifies: How does this part help the plant?	Identify root and its role	1.38	.82	0	2	2.00
	Identify stem and its role	1.52	.69	0	2	2.00
	Identify leaves and their role	.87	.51	0	2	1.00
	Identify flowers and their role	.83	.67	0	2	1.00
	Identify fruit and its role	.01	.11	0	2	.00
	Identify seeds and their role	.71	.86	0	2	.00

Table 5.2 (cont'd).

Question	Performance Expectation	M	SD	Min	Max	Median
Question 3: What does a plant need to grow? For each plant requirement a student identifies: How does this item help the plant grow?	Identify air and its role in plant growth	.27	.48	0	2	.00
	Identify light and its role in plant growth	.85	.45	0	2	1.00
	Identify water and its role in plant growth	.95	.27	0	2	1.00
	Identify nutrients and its role in plant growth	.10	.33	0	2	.00
	Identify space and its role in plant growth	.05	.27	0	2	.00
Question 4: How does a plant (e.g., apple tree) change over time? (e.g., How does it start? What happens next?)	Identify stages in life cycle of plant	1.73	.57	0	2	2.00
Totals		10.99	2.65	5	17	11.00

plants assessment could range from zero to 26 points. Table 5.2 provides the means, standard deviations, minimum, maximum, and median for the individual plants concepts assessed and the overall prior knowledge plant score.

Out of a possible 26 points, students' average total score on the plants assessments was 10.99 (SD=2.65) points. The final scores ranged from a minimum of five points to a maximum of 17 points. A histogram of these scores showed many scores clustering near the median score (11.00). A closer look at students' responses show that they were more likely to know about observable plant parts, plant requirements, and stages of growth and less likely to understand underlying purposes or functions.

In the first question, students identified examples of plants and non-plants provided to them and then generated some additional examples on their own. The majority of students (66 of 84) identified all examples correctly while 22 students identified most examples correctly. Only one student showed limited understanding of this concept and identified only a couple examples of plants and non-plants accurately. Students provided copious examples of plants (e.g., grass, bushes, cactus, rose, vegetables, fruits, daisy, cattails, tulips,) and non-plants (e.g., chairs, pencils, desk, door, hose, clock, rabbit, balls, clothes) in their responses. The greatest confusion arose in determining whether or not a dandelion and a tree were plants. For example, some students knew that dandelions were weeds and thought that this distinction meant they were not plants. In addition, some students stated that particular plant parts were plants (e.g., leaves) while others thought that "anything that's connected to the earth like dirt or soil…is a plant." Many students had intimate knowledge of different types of plants and non-plants – all observable, tangible phenomena.

The second part of the interview focused on plant parts and their functions. On average students had the fullest understanding of the stem (M=1.52, SD=.69) and the root (M=1.39, SD=.82). The majority of students' responses revealed adequate understanding of the stem (51 students) and root (55 students) and their functions. After identifying the root as a plant part, students talked about how the roots "suck in water for the plant," "dig it into the ground so it won't blow away," "absorb the water which comes up the stem and goes to leaves," and "helps it stay in place so it doesn't fall over." Students commented that the stem "connects to the roots and the roots take up the water and it goes through the stem… to the flower," "it holds it up and…transfers the water to the seeds up in the flower," and

> It helps them suck up the water because it's kind of like tube to get it up to the flower petals. And it makes it stand up a bit. It would be funny if there was no stem and there was just a flower sitting on the ground.

In contrast, 18 students did not identify the roots as a plant part and nine students did not identify the stem as a plant part.

Students revealed lower levels of understanding of the leaves (M=.87, SD=.51), flowers (M=.92, SD=.63), and seeds (M=.71, SD=.86); they frequently identified these plant parts, but had more difficulty correctly identifying the role of each one. Only six of the 84 students accurately stated the function of the leaves (e.g., "it makes a kind of food for the plant;" "meant for absorbing sunlight and…in the leaves is where they build the food for the plants"). Sixty-one students identified the leaves as a plant part but did not know their function while 17 students never mentioned the leaves. Similarly, most students (51 of 84) identified the flowers as a plant part but only 13 students correctly stated the function of the flowers in their responses. For those who did, they discussed the flowers' critical role in pollination (e.g., "that's where the seeds are…without a flower the bees can't come over and pollinate it"). Twenty-two students discussed the seeds and their role accurately, 16 students identified the seeds as a plant part but did not mention their function, and 46 students did not identify the seeds at all. When students talked about the role of the seeds, they discussed their importance in reproduction and making new plants. It was uncommon for students to identify the fruit as a plant part; only one of the 84 students mentioned this plant part in the interview.

The third interview question focused on plant requirements and their role in plant growth. The best understood plant requirements were water (M=.95, SD=.27) and sunlight (M=.85, SD=.45). However, only a few students (three students for sunlight and one student for water) accurately discussed the function of these requirements. Instead, students provided less specific ideas about the function of water and sunlight. For example, many students talked in general terms about how water was needed for the plant's survival and water helps the plant grow bigger and stronger. When discussing the function of the sunlight, it was not unusual to hear students talk about how the sun helps the plant grow (most common statement), warms the plant, and gives energy to the plant. However, none of these responses addressed water's role in helping make and move nutrients or sunlight's role in producing food for the plant. Some students did not bring up sunlight (16 students) or water (5 students) in their discussion of plant requirements.

Students lower levels of understanding and awareness of air (M=.27, SD=.48), nutrients (M=.11, SD=.34), and space (M=.05, SD=.27) as plant requirements. Even students who mentioned these requirements almost never accurately identified their role; in fact, this occurred only once for each requirement, with each requirement mentioned by a different student. Twenty-one students identified air as a requirement but did not accurately state its role in plant growth. For example, students shared other ideas, which were not counted as accurate and compelte, about the function of air including "it helps the plant breathe," "helps the plant grow," and "without oxygen the plant would suffocate and die." Seven students identified nutrients as a plant requirement but did not talk about how they help the plant to be healthy; two students talked about the importance of space without correctly identifying how space allows the plant to expand and grow. Most students (62 students for air, 76 students for nutrients, and 81 students for space) never discussed these plant requirements.

The last question in the prior knowledge interview targeted students' understanding of the four key stages in the life cycle of a plant (i.e., seed, plant, flower, and fruit). Of the 84 students, sixty-six correctly identified all four stages in the plant life cycle in order (adequate understanding) while 13 students identified at least three stages in the life cycle (developing understanding). Only five students identified two or fewer stages (limited understanding). Table 5.3 presents examples representing students' limited, developing, and adequate understanding of the stages in a plant's life cycle.

Table 5.3. Examples of Students' Responses to Question about a Plant's Life Cycle

Coding	Examples
Limited Understanding	It starts out as a stem. And then the leaves come out of the top and then it grows up to be a little taller. And when it comes to summer it blooms.
Developing Understanding	It [apple tree] starts out as a seed and it turns into a small tree and then it turns into a really big tree and apples grow on it. Then the apples fall off in the fall and then leaves come back in spring and then in summer the apples come back. It starts out by a seed and then the seed grows roots and then the flower opens and comes out of its little nap time. Then it has the stem and then the leaves and the middle part and then it has the petals.
Adequate Understanding	It turns into a seed and then the seed breaks and a sprout comes out of the dirt. And grows with water and the sunlight and ends up going pretty tall and ends up a flower. That's all I really know. *(Interviewer: What would change about that if that was an apple tree?)* It would turn into a flower at first and then it would turn into an apple A tree does the same thing, the seed grows and grows and then, well it grows a stem and the roots come out, then it goes up out of the ground. It gets the leaves, petals and the branches and then it grows the leaves and the apples come from the branches.

Taken together, these responses show that students were more knowledgeable about observable things, such as actual plants, the stages of plant growth, and visible plant parts; they were less knowledgeable about the invisible mechanisms used to explain why plants function and grow as they do. What remains to be seen, though, is whether students used this topic-specific knowledge to generate inferences and comprehend the informational and data science texts. In the next section, I present results to show that students use their topic-specific prior knowledge to generate all three types of inferences and that prior knowledge was a key factor related to students' comprehension across all four texts.

Drawing Upon Topic-Specific Prior Knowledge to Generate Inferences

In order to generate inferences, students could rely upon three possible knowledge sources. First, they could activate their prior knowledge and apply this knowledge to generate explanations, predictions, or associations while reading. This knowledge source comes from outside the text. The other two knowledge sources are text-based. Students could maintain or retrieve ideas from the text or prior think aloud comments to generate inferences. The key difference between the maintenance and retrieval of ideas is the distance between the inference and its source. If the source of the inference is only two sentences away, then the student is said to be maintaining that idea from his/her short term memory to generate the inference. However, if the source of the inference is more than two sentences away, then the student is considered to be retrieving that idea from his/her long term memory.

It is important to know the source for students' inference generation for two reasons. First, as I showed in the previous chapters, inferences formed a large portion of the strategies that students used to comprehend these texts. Thus, this information will form a more complete picture of students' strategy use – going beyond what inferences they generate to how they generate those inferences. Second, by understanding what students do and do not draw upon to make inferences we will be better positioned to help them draw inferences with future science texts (Of course, the importance of supporting students' inference generation assumes that inferences are related to students' text comprehension, an idea which will be explored later in this chapter).

Overwhelmingly students relied upon the activation of their prior knowledge when generating explanations, predictions, and associations. On average across all four texts, 76.94% (SD=12.48) of the inference idea statements involved activation of students' prior knowledge compared with 13.37% (SD=7.01) drawing upon maintenance (SD= 7.01) and 9.78% upon retrieval (SD=11.49) of prior text statements or think aloud comments. This same pattern – a reliance on activation of prior knowledge and considerably less reliance on the maintenance and retrieval of ideas – is evident within each text and inference type (explanation, prediction or association) as well. These findings provide empirical evidence that students' prior knowledge is an importance source for inference generation, independent of the texts used in this study. Tables 5.4 and 5.5 provide descriptive statistics for students' use of the three knowledge sources by text and by inference type, respectively. I will provide examples from students' think aloud comments to describe in more detail how students relied upon each of these knowledge sources when generating inferences.

Activation. Students were most likely to generate inferences by activating their prior knowledge. On average students used this knowledge source to produce 76.94% (SD=12.48) of the inferences across all texts. Students activated their prior knowledge for the greatest percentage of inferences when reading the sound informational text (M=83.82, SD=14.17) and for the least percentage of inferences with the plants informational text (M=74.13, SD=16.40). The median percentage of inferences leveraging prior knowledge was 77.07, which is close to the mean. Students

Table 5.4. Descriptive Statistics for Percentage of Knowledge Sources Used by Text

Texts	Knowledge Sources	M	SD	Min	Max	Median
	Activation	83.82	14.17	50	100	85.71
Sound – Informational	Maintenance	9.90	9.90	0	37.50	9.09
	Retrieval	6.28	8.66	0	36.36	.00
	Activation	75.66	15.44	50	100	75.00
Sound – Data	Maintenance	13.19	12.56	0	50	11.76
	Retrieval	11.15	10.99	0	45.45	8.33

Table 5.4 (cont'd).

Texts	Knowledge Sources	M	SD	Min	Max	Median
Plants – Informational	Activation	74.13	16.40	0	100	75.00
	Maintenance	13.66	11.59	0	50	13.33
	Retrieval	12.21	13.87	0	100	9.09
Plants – Data	Activation	79.78	20.58	0	100	83.67
	Maintenance	15.34	17.30	0	75	10.00
	Retrieval	4.87	12.43	0	100	.00
All Texts	Activation	76.94	12.48	0	100	77.70
	Maintenance	13.37	7.01	0	40	13.37
	Retrieval	9.78	11.49	0	100	8.83

Table 5.5. Percentage (standard deviation) of Knowledge Sources by Inference Type across Texts

Texts	Knowledge Sources	Percentage of Explanations		Percentage of Predictions		Percentage of Associations	
		M	SD	M	SD	M	SD
Sound – Informational	Activation	81.50	27.36	87.80	20.01	82.62	19.59
	Maintenance	14.93	25.66	8.40	17.42	9.47	12.63
	Retrieval	2.71	9.00	3.80	10.96	7.91	12.51
Sound – Data	Activation	77.27	18.49	76.03	28.98	73.16	35.13
	Maintenance	12.29	14.19	12.00	19.45	13.57	25.67
	Retrieval	10.44	12.28	11.97	25.30	13.27	24.78

Table 5.5 (cont'd).

Texts	Knowledge Sources	Percentage of Explanations		Percentage of Predictions		Percentage of Associations	
		M	SD	M	SD	M	SD
	Activation	79.17	29.83	66.38	30.05	77.72	23.94
Plants – Informational	Maintenance	18.94	30.18	10.23	17.46	15.63	21.55
	Retrieval	1.89	6.54	22.06	26.36	6.65	14.51
	Activation	85.93	20.95	84.34	21.64	78.05	27.73
Plants – Data	Maintenance	11.48	18.74	11.98	20.01	16.19	23.76
	Retrieval	2.59	8.44	2.94	8.76	5.76	15.00
	Activation	79.75	14.64	74.74	17.88	76.98	16.45
All Texts	Maintenance	13.32	11.45	12.94	16.00	14.07	10.94
	Retrieval	6.86	8.05	11.44	12.54	9.35	13.51

appear more likely to use text ideas as a prompt to access their prior knowledge than to integrate pieces of information within the text.

When reading the sound data text, many students drew upon their previous experiences of physically moving part of an object in order to produce sound and their knowledge of vibrations to explain why the objects in the text were moving and making sound. For example, many students mentioned that the reason the thumb plucker moves up and down is because it was plucked by someone, while other students explained that the thumb plucker is vibrating. Students activated other background knowledge while reading the sound data text, including ideas about additional ways to change the volume or pitch of an object (e.g., "push not very hard to…make a soft sound;" "pull it far, far out and it'd be a higher sound") and reasons to explain differences in volume or pitch (e.g., "I…hear a higher sound because it doesn't vibrate as much;" "you hear a low sound because it has less room to travel").

Students activated their prior knowledge while reading the sound informational text too. Some common ideas stated in their think aloud comments for this text consisted of statements about how to make sounds with different pitches and volumes; reasons to explain why loud sounds vibrate more air, why slow vibrations make low pitched sounds, and why a bird's chirp is high; examples of objects that can produce sound; and information about what happens to the sound wave once it enters your ear. When generating inferences as they interacted with the texts about plants, students also engaged in frequent activation of their prior knowledge. Students relied upon their knowledge of the function of different plant parts, what happens as a plant grows over time (the different steps in the process), conditions of growth, life cycles of plants, and how plants grow as they provided explanations, made predictions, and formed associations.

Maintenance. Compared to activating prior knowledge, students were less likely to maintain ideas from previously read text ideas or think aloud comments to generate inferences. On average across all four texts students maintained ideas to generate 13.37% (SD=7.01) of the inferences. Students would generate inferences by relying upon information that had been recently stated in the written text or in a prior think aloud comment. For example, when explaining why the air in a bird's throat vibrates fast, one student relied upon a recently stated text idea about a bird's chirp being high. The student used this information to determine that the air vibrating fast creates high pitched sound waves. Similarly, another student explained that loud sounds vibrate more air "because louder sounds are like bigger;" this explanation drew upon a recent idea stated in the text ("Big sound waves make louder sounds.").

Students' generalizations, which are one type of association, frequently relied upon ideas maintained close by in the text. For example, after reading observations about hearing a high sound when you pluck a short stick, one student used this idea to generalize that "the short[er] you do it the higher it is." In a different example, one student detailed in what ways the roots, stem, and leaves of the plant look the same; when doing so, he drew upon a similar idea, which he had stated two sentences ago while thinking aloud.

Retrieval. Like maintaining ideas, students did not rely upon retrieval of ideas extensively when generating inferences. On average across all four texts students generated 9.78% (SD=11.49) of their inferences by retrieving ideas from past text ideas or think aloud comments. One common pattern for retrieving ideas occurred near the end of the plants informational text, which ends by stating that "acorns grow fat in the spring and summer." Many students responded to this sentence by making predictions about what would happen to the acorns next (e.g., "They start to get bigger and then they drop."). In this case, students retrieved information that had been stated in the first few sentences of the text (e.g., "acorns drop on the ground in the spring") to generate the prediction about the acorns falling to the ground.

Another way that students would retrieve ideas was to rely upon previous explanations they had given to elucidate particular observations. For example, one student talked about how one uses more force to create a louder sound with the thumb plucker. Then, when reading about producing a loud sound with the rubber band strummer, this student retrieved this previously mentioned idea (that more force creates a louder sound) and applied it to the new situation. He used this idea to explain why the rubber band strummer is making a loud sound (because the student used more force to pluck the rubber band). Another student mentioned that he could feel the ruler shaking because it is vibrating; he had already discussed the role of vibrations in producing sound when talking about why you can see parts of the thumb plucker and rubber band strummer moving.

Relationship with students' strategy use. In order to further explore the relationship between prior knowledge and students' strategy use, I calculated correlations between students' prior knowledge scores on each topic – sound and plants - and the number of idea units, inferences, non-inferences, and different types of think aloud comments (e.g., explanations, metacomments, etc.) they produced while interacting with the various texts. I used the appropriate topic-specific prior knowledge score to examine these relationships for each text (e.g., I used the sound prior knowledge score to examine these relationships for the sound texts). Table 5.6 provides these correlations by text.

Table 5.6. Correlations between Students' Topic-Specific Prior Knowledge (PK) and Strategy Use Variables by Text

Variables	Sound Informational Text	Sound Data Text	Plants Informational Text	Plants Data Text
Idea units	.312**	.228*	.187	.231*
Inferences	.246*	.224*	.275*	.222*
Non-inferences	.227*	.089	-.036	.108
Inaccurate ideas	-.126	.065	-.188	-.114
Explanations	.254*	.227*	.181	.187
Predictions	.125	.011	.185	-.005
Associations	.183	.135	.196	.257*
Paraphrases	.217*	.161	-.061	.035
Metacomments	-.004	-.077	-.026	.027
Personal connections	.101	.055	.153	.147
Questions	-.046	-.051	-.087	-.014
Visualizations	.045	-.163	.085	.035
Personification	A	a	-.061	.114
Incomprehensible	.117	-.048	-.018	-.173

[a] Correlations could not be obtained.
*p < .05, **p < .01

The correlation between students' prior knowledge and the number of idea units produced was statistically significant for three of the four texts. Higher prior knowledge scores are associated with a greater number of idea units produced in students' think aloud comments for both informational texts and the sound data text. The relationship between students' prior knowledge and the number of inferences they generated in their think aloud comments is also significantly correlated across all texts. Students who possess a greater knowledge of specific scientific concepts related to sound and plants were more likely to generate more inferences in their think aloud comments for that same topic. In only a few cases, specific comment types were positively correlated with higher prior knowledge scores.

It is important to note that all of the correlations reported are relatively weak. That is, only a small percentage of the variation in these various outcome measures can be explained by students' prior knowledge. For example, 6% of the variance in the number of inferences students generated while interacting with the sound informational text can be explained by their sound prior knowledge scores; a similar pattern exists for the other texts – 5% for the sound data text, 7.6% for the plants informational text, and 4.9% for the plants data text. This may be due to the fact that the prior knowledge interviews only addressed a portion of students' background knowledge on a particular topic and students drew upon other experiences and knowledge they had relating to these topics.

Summary. Across all four texts findings showed that students relied extensively on their prior knowledge to generate all three types of inferences; they generated only a small percentage of inferences by maintaining or retrieving ideas from text statements or prior think aloud comments. In addition, correlational analysis shows that students with higher prior knowledge scores are more likely to generate a greater number of total inferences during reading. These findings are important because they let us see the vital importance of topic-specific prior knowledge for inference generation; students are more likely to generate inferences when they have relevant topic-specific prior knowledge to access. This does not mean that prior knowledge is a requirement for inference generation (we did see students rely on the text to generate inferences), but it may be that prior knowledge acts as an important resource for student' inference generation.

Comprehension: The Relative Importance of Prior Knowledge and Strategy Use

As noted in the methods section, after reading each text, each student answered a series of six comprehension questions to assess their explicit and implicit understanding of key ideas from the text. Three questions targeted ideas that were explicitly addressed in the text while three questions focused on ideas that were implied by text ideas. Appendices I to L provide sample student responses to the comprehension questions for each text at the three levels of scoring (full credit, partial credit, and no credit). The overall goal was to use these scores to investigate the relationships between students' prior knowledge and strategy use and their comprehension. Specifically, I wanted to see how well the findings from this study mapped onto the original conceptual model, which posits that particular individual and text characteristics prompt students' strategy use, which in turn affects students' comprehension. Before delving into these findings, I first present results regarding students' comprehension scores for the four texts to set the stage for this final analysis.

Students' comprehension: Recall is easier than integration of ideas. Table 5.7 displays the means and standard deviations for explicit, implicit, and overall comprehension scores by text. The explicit comprehension score represents the accuracy of students' responses to three explicit, or recall, questions about information directly stated in the text while the implicit comprehension score is for the three questions that required students to draw upon text ideas and/or their background knowledge to answer correctly. The overall comprehension score is a compilation of students' scores on the explicit and implicit comprehension questions. For each text, students could score a total of six points for explicit and implicit comprehension separately and a total of 12 points for overall comprehension. As I will show in the next two sections, on average students answered the explicit questions more accurately than the implicit questions, which makes sense since the former ones assess students' recall of text ideas and the latter ones target students' ability to integrate information from various places. This pattern can be found within each text. I report the results associated with the sound texts and then the plants texts.

Table 5.7. Means (standard deviations) for Explicit, Implicit, and Overall Comprehension Scores By Text

Comprehension	Sound – Informational[a]	Sound – Data[a]	Plants – Informational[a]	Plants – Data[a]
Explicit	4.61 (1.11)	5.57 (.97)	4.89 (1.46)	4.67 (1.10)
Implicit	2.00 (1.58)	4.24 (1.45)	4.42 (1.79)	4.12 (1.81)
Overall	6.61 (2.20)	9.81 (2.01)	9.31 (2.62)	8.79 (2.45)

[a] n=84 for each text

Sound. Within both texts, on average students' scores for the responses to the explicit questions were higher than their scores for the responses to the implicit questions, although this difference was more pronounced for the sound informational text. Post hoc paired t-tests showed significant differences between students' scores on the explicit and implicit comprehension questions for the sound informational text, $t(83)=14.880$, $p < .001$, and the sound data text, $t(83)=8.522$, $p < .001$. There appears to be a bit of a ceiling effect for students' scores on the explicit questions for the sound data text. The average score ($M=5.57$, $SD=.97$) was close to the total possible score of six points. Students could easily answer the explicit questions correctly after reading the sound data text. Upon closer inspection, there are distinct patterns in students' responses to these questions.

For the sound informational text, most students were unable to provide an accurate reason for why the lion's roar is low. Common, but incorrect, answers for this question included ideas about the lion being heavier than other animals, not having as much air in its throat, or because it makes a loud sound. In addition, students talked about how loud sounds are made, such as hitting objects harder, or gave many inaccurate answers for why loud sounds have a loud volume, such as loud sounds are made from bigger things or caused by slower vibrations. When looking across students' responses to the explicit questions for this text, one prominent pattern is that many students could not describe how a sound wave is moving air, but instead described features of a sound wave (e.g., cannot see it, carries sound) or one part of the answer (e.g., sound in the air, sound that travels). However, almost all students identified that sound can have a high or low pitch and talked about specific ways that sound can be made (e.g. by hitting objects, playing instruments).

In response to the explicit questions for the sound data text, students frequently stated that one would see the rubber band vibrating, hear the ruler slapping the table, and feel the popsicle stick hitting his/her thumb. It was rare for students to not recall this information from the observations they read. Likewise, many students correctly answered the first two implicit questions for the sound data text. When answering the question about how sound is made, many students correctly talked about the importance of movement or vibrations. Similarly, it was common for students to identify a variety of ways that sounds are different from each other – how they differ in pitch or volume – after interacting with this data. However, students had a more difficult time explaining how you hear the ruler from across the room. Instead of describing a complete model (e.g., ruler hits the table causing sound waves to travel through the air to your ear), many students mentioned only one or two parts of the model or explained that you could hear the ruler because it is loud. Students' greater difficulty answering the final implicit question might have to do with the increased level of abstraction from the observations mentioned in the sound data text.

Plants. Similar to the results for the sound texts, on average students' responses to the explicit questions were more accurate than their answers to the implicit questions, although this difference for both plants texts was minimal. Post hoc paired t-tests showed significant differences between students' scores on the explicit and implicit comprehension questions for the plants informational text, $t(83)=2.240$, $p < .05$, and the plants data text, $t(83)=2.934$, $p < .01$.

For the plants informational text, most students correctly identified that the acorns grow on the branches, talked about how the acorn cracks open and grows into another oak tree after it falls to the ground, and mentioned that the sprout grows leaves and turns into an oak tree. Common errors in students' answers to these explicit questions included incorrectly identifying the leaves as the location for acorn growth, confusing the sprout with the roots, and not knowing what the sprout is. The greatest confusion with respect to the implicit questions for this text stemmed from students' responses to the question about why the oak tree grows flowers. About a third of the students did not recognize the connection between the flowers and the acorns and instead talked about how the flowers make food for the plant or help the leaves grow. About 25% of the students did not realize that the acorns fall off the tree in order for new oak trees to grow or did not know that the acorn is the seed.

For the plants data text, the majority of students accurately recalled that the roots of the pumpkin plant grow bigger and longer and the stem grows thicker and longer. In addition, most students identified four or more of the steps in a pumpkin plant's growth; they were mostly likely to forget about one of the stages in the middle (e.g., stem, leaves, or flowers). For the implicit questions, most students were aware that the seed breaks open in order for the pumpkin to grow, specifically, for the roots and stem to begin growing. A little more than a third of the students did not know the function of the roots or the reason the pumpkin plant grows flowers.

Inference generation and comprehension: A positive, but weak, relationship. One hypothesis based on the literature review was that students who generated more inferences while reading would be more likely to comprehend the text better. This hypothesis was based on the widely accepted idea that good readers generate inferences as they make sense out of text ideas and inferences facilitate the development of a coherent situation model, which promotes comprehension. Thus, I examined the relationship between students' scores for overall, explicit, and/or implicit comprehension and their strategy use. Appendices P to S show correlations between students' comprehension scores and variables related to students' strategy use by text.

For all four texts, there was a statistically significant correlation between the total number of inferences produced and students' overall, explicit, and/or implicit comprehension scores. For the sound informational text ($r=.306$, $p < .01$), the sound data text ($r=.218$, $p < .05$), and the plants data text ($r=.312$, $p < .01$), higher scores on the overall comprehension questions were associated with a greater number of total inferences. Students who generated more inferences while reading the sound informational text ($r=.318$, $p < .01$) and the plants data text ($r=.236$, $p < .05$) were more likely to have higher scores on the explicit comprehension questions and students who produced more inferences while interacting with both plants texts [plants informational ($r=.258$, $p < .05$) and plants data ($r=.281$, $p < .01$)] were more likely to have higher implicit comprehension scores.

There were a few statistically significant correlations between students' comprehension scores and strategies exhibited in their think aloud comments. For the sound informational text, a greater number of explanations was associated with higher scores for overall ($r=.342$, $p < .01$), explicit ($r=.357$, $p < .01$), and implicit ($r=.227$, $p < .05$) comprehension questions. In addition, students who generated more associations ($r=.241$, $p < .05$) and paraphrases ($r=.235$, $p < .05$) were more likely to have higher scores on the explicit questions. For the plants informational text, a greater number of predictions were associated with higher scores on the implicit comprehension questions ($r=.216$, $p < .05$). Lastly, for the plants data text there was a statistically significant positive correlation between the number of associations and all three comprehension scores [overall ($r=.312$, $p < .01$), explicit ($r=.236$, $p < .05$), and implicit ($r=.281$, $p < .01$)] as well as a significant negative correlation between students' overall ($r=-.267$, $p < .05$) and explicit comprehension scores ($r=-.258.$, $p < .05$) and the number of incomprehensible statements. This finding means that a greater number of incomprehensible statements were associated with lower overall and explicit comprehension scores on the plants data text.

Prior knowledge and comprehension: A stronger relationship. As I pondered these positive, but weak, correlations between students' inferences and their comprehension, I realized that students' had stated many of these same ideas in their prior knowledge interviews. So I examined the relationship between students' scores for overall, explicit, and implicit comprehension and their prior knowledge scores. Table 5.8 provides the correlations for these relationships by text.

Table 5.8. Correlations between Students' Topic-Specific Prior Knowledge (PK) and Overall, Explicit, and Implicit Comprehension by Text

Comprehension	Sound Informational Text	Sound Data Text	Plants Informational Text	Plants Data Text
Overall	.527**	.407**	.493**	.558**
Explicit	.432**	.213	.327**	.324**
Implicit	.432**	.421**	.455**	.560**

*p < .05, **p < .01

For all four texts, there were statistically significant, moderate correlations between students' topic-specific prior knowledge and their overall comprehension scores. For all four texts, higher scores on the overall comprehension questions were associated with greater topic-specific prior knowledge. Likewise, students who scored higher on the implicit comprehension scores also had more prior knowledge. This same positive correlation also exists between prior knowledge and students' explicit comprehension scores for three texts; there was not a statistically significant correlation between students' prior knowledge and explicit comprehension for the sound data text, which is not surprising since these three questions are directly related to the three sound systems in this text. Students were unlikely to know about these three specific sound systems before reading the text so that students did not draw upon their background knowledge to correctly answer the explicit questions for this text. All of these positive correlations were moderate in strength, which suggests topic-specific prior knowledge is an important factor that should be accounted for in any analysis that examines the relationship between students' strategy use and comprehension.

Developing a Linear Regression Model: What Predicts Students' Comprehension?

In the final step of the analysis, I used information gleaned from the statistical analyses to develop a linear regression model to determine what factors predict students' comprehension for each text. Correlation analyses showed that for each text students' prior knowledge was positively, but weakly, related to strategy use and moderately related to comprehension. In particular, these findings showed that specific strategies, specifically the three types of inferences and paraphrases, were correlated with students' prior knowledge and their comprehension for particular texts. Since other potential predictors (e.g., number of other non-inference strategies) were not correlated with students' comprehension, I did not include them in the final model. Table 5.9 shows the results of the linear regression analyses predicting comprehension by text.

For all four texts, prior knowledge was a significant predictor of students' comprehension. That is, students' prior knowledge scores can be used to predict anywhere from 16.5% (for the sound data text) to 31.1% (for the plants data text) of the variance in students' comprehension scores. In terms of the other possible predictors (number of explanations, predictions, associations, or paraphrases), only two comment types made a difference in predicting students' comprehension above and beyond prior knowledge for particular texts. For the sound informational text, after accounting for students' prior knowledge the number of explanations accounted for a statistically significant percentage of the variance in students' comprehension. For the plants informational text, the number of paraphrases explained a statistically significant percentage of the variance in students' comprehension, after accounting for students' prior knowledge. However, it is important to note that although these other strategies accounted for a statistically significant portion of the variance in students' comprehension scores, the additional change in r squared was not large for either. Prior knowledge is by far the best predictor for students' comprehension of each text in this study. Surprisingly, even though previous analyses showed that students used their prior knowledge to generate inferences it appears that the use of only one inference type – explanations – is related to students' comprehension of science texts - and this relationship was discovered for only one of the texts (sound informational text). This finding will be discussed in more detail in chapter seven.

Table 5.9. Linear Regression Analyses Predicting Comprehension from Prior Knowledge and Number of Explanations, Predictions, Associations, and Paraphrases

	Sound Informational Text		Sound Data Text		Plants Informational Text		Plants Data Text	
Predictor	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β
Step 1	.277***		.165***		.243***		.311***	
Prior knowledge		.532***		.376***		.486***		.516***
Step 2	.047*		.017		.011		.004	
Explanations		.240*		.052		.113		.058
Step 3	.007		.003		.001		.015	
Predictions		.065		-.046		.021		.110
Step 4	.002		.018		.007		.029	
Associations		.025		.103		-.072		.146
Step 5	.003		.001		.055*		.026	
Paraphrases		.026		.010		.114*		.077
Total R^2	.337***		.204**		.318***		.386***	
N	84		84		84		84	

*p < .05, **p < .01, ***p < .001

Chapter 6: Putting It All Together: The Case of Bobby

In this last results chapter, I provide a detailed description of the strategies one student used to comprehend the different science texts and his prior knowledge and comprehension related to each text. My goal is to use this case as an exemplar to better illuminate the relationships between prior knowledge, text interactions, and comprehension. I selected this student purposefully to illuminate the patterns that emerged from the data analysis.

Bobby is an eight year old, third grade student who is an above grade level reader. He was assigned to condition four, which meant that he read the informational texts first (sound and then plants) and the data texts last (sound and then plants). I begin by summarizing his responses to the prior knowledge interview and then examine his text interactions and comprehension.

Prior Knowledge: A Developing Understanding of Sound and Plant Concepts

Bobby's responses to the prior knowledge interview revealed that he possessed a developing understanding of many concepts related to sound and plants. Overall Bobby scored nine out of 14 total points on the sound assessment, which is a little more than one standard deviation above the mean. On the plants assessments, he scored twelve out of 26 total points, a score that is about a half standard deviation above the mean.

Sound. Bobby's responses to the sound interview questions showed that he had an adequate understanding of what one can do to make sound and how sound is made, but was only beginning to understand concepts related to changes in volume and pitch. Bobby mentioned that you need to hit something and it "makes the vibrations and the vibrations go into your ear." He correctly identified all situations when sound is and is not made and even provided some examples of his own (e.g., typing on the computer and jumping in the pool versus a book lying on the ground). He also knew that you could use a thin rubber band to make a higher pitch and a thick rubber band to make a lower pitch with the rubber band instrument, but was unsure of the reason for the change in pitch. Bobby also mentioned that the "vibration would be really loud" if you pulled the rubber band hard and flung it back but could not provide any explanation for this phenomena. Although Bobby was able to describe how to make these, he confused volume and pitch (i.e., when asked about how to change the pitch he talked about changes in volume and vice versa). For example, when I asked him to explain how to change the volume of the rubber band box instrument, Bobby said "if it's thick or if it's like skinny" and went on to discuss how the thick rubber band would make the sound low and the skinny rubber band would make the sound higher. Likewise, when I asked him how to change the pitch of the rubber band box instrument, Bobby commented that you could "pull it really hard and it would make a big sound," which is about changing the volume of the sound.

Plants. Like many students, Bobby correctly identified whether a flower, tree, cow, dandelion, and person were plants or not and provided examples of other plants he was familiar with (rose, grass, lily pad, and cattails), as well as items that are not plants (books, soap, fan, and coffee cup). He correctly discussed the function of the roots, which was to "get water for the plant" and "hold the plant down inside the dirt," and the function of the stem to "bring the water up into the flower." Although he knew about the leaves and the flower, Bobby was unsure how they helped the plant. Bobby named two plant requirements – water and sunlight – and commented that they made the plant stronger; however, he did not know the specific role for each one. Lastly, he revealed an adequate understanding of a plant's life cycle, naming all four stages (seed, plant, flower, and fruit) in the correct order.

Summary. In Bobby's responses to the sound questions, we see that he knows how to make sound and how to change some of the characteristics of sound. He also has a beginning understanding of how sound is created (by vibrations) and how we can hear sound (vibrations travel to our ears), but is unable to draw upon this knowledge to explain why sound changes pitch and volume. In addition, we see that he knows about many of the observable features of plants and plant growth, but does not have a well developed understanding of the mechanisms to explain how and why plants grow. This pattern is similar to what we found across students' prior knowledge responses: greater knowledge of the observable features of real-world phenomena and less understanding of model-based reasons that explain these observations.

Text Interactions: Using Prior Knowledge to Generate Inferences

Bobby's think aloud comments for each text are representative of the overall text interaction patterns revealed in the analysis reported in previous chapters. Across all four texts, his think aloud comments were dominated mainly by inferences and paraphrases; sixty percent or more of the total idea statements coded for each text were explanations, predictions, or associations, while approximately 20 percent of the idea statements were paraphrases. Bobby's interactions with these four science texts revealed similar variation by text type and topic to that observed in the full data set. He was most likely to generate associations while interacting with the sound informational text, explanations with the sound data text, a combination of predictions and associations with the plants informational text, and associations with the plants data text. In addition, his strategy use seems to be related to his prior knowledge on each topic; that is, there is evidence in each text that he draws upon this knowledge when generating inferences, some more so than others.

Sound informational text. When reading the sound informational text, Bobby generated a substantial number of inferences, and a majority of these inferences were associations. Eighty-two percent (18 of 22) of the idea statements were inferences, which included twelve associations, three predictions, and three explanations. Bobby provided a plethora of associations, commenting about features of the sound wave (can't see it) and where the sound goes ("hits your ear drum"). He generated a few explanations; for example, while reading about the lion's roar being low, he stated that it was because the air moved slowly. Similarly, after reading that sounds are louder when they are close, Bobby mentioned that was due to the fact that the "sound waves go in your ears faster." In addition, he made a few predictions in response to some text ideas. For example, he predicted that the sound wave would not be that loud if you tapped more lightly on the drum and that if you hit the drum faster you can make a higher pitched sound. This last prediction is inaccurate. Bobby also made a couple of paraphrases and visualizations. For example, after reading about how "objects make sound when they move" and "the moving air is called a sound wave," Bobby mentioned that he was picturing a person running on cement making sound and a person clapping their hands to make sound waves.

Many of the inferences (15 of 18) relied upon Bobby activating his prior knowledge, and we see a connection to some of his prior knowledge interview responses. For example, it was clear that before interacting with the sound informational text Bobby understood that objects need to move to make sound and could provide examples to support this pattern. In his think aloud comments, he used this prior knowledge to elaborate on the text and gave examples of ways to make sound (running, clapping, hitting a drum). Bobby also possessed a developing understanding of how sound is made and he used this information to make additional associations about the text ideas (e.g., commenting about where the sound goes and what it does). In addition, he continued to confuse volume and pitch in his think aloud comments, just like in his prior knowledge interview. For example, in his think aloud comments after reading that "sounds have different volumes" he talked about ways to make low pitched and high pitched sounds. Other ideas from his background knowledge, such as sound fading when it travels and sound waves going faster in your ear when you are closer to an object, were used to generate inferences, although these ideas were not the focus of the prior knowledge interview.

Sound data text. Approximately half (twelve of 25) of the idea statements Bobby made about the observations were explanations. As revealed in the larger data set, on average students generated a greater number of explanations when interacting with the sound data text. Bobby's think aloud comments fit this pattern. The majority of these explanations attempted to address the reason for the current state of different objects and why the student heard particular sounds. For example, he explained why the student heard a low sound when he plucked the popsicle stick ("because…the sound wave is going slowly"), why he heard a soft sound on the rubber band strummer ("cause…you're not putting much strength on it"), and why the ruler is moving up and down fast ("because…you pulled it"). In addition to these explanations, Bobby produced some associations (five of 25 idea statements), which mainly focused on elaborating how the different objects moved, and some paraphrases (six of 25 idea statements). Like his interactions with the earlier text, Bobby activated his prior knowledge to generate the majority of these inferences (13 of the 18 inferences).

There is some evidence that Bobby used ideas mentioned during his prior knowledge interview in his think aloud comments for the sound data text. For example, he knew that objects need to move to make sound and used this knowledge to explain why specific objects mentioned in the text were moving and making sound (e.g., the ruler moved because the student "pulled it down"). Likewise, Bobby knew that vibrations enter into your ear and used this prior knowledge to explain what was happening in the rubber band strummer so you could hear the hollow sound (e.g., "the sound waves are going inside the cup and they're bouncing off the cup"). In addition, he drew upon other background knowledge, which was untapped by the prior knowledge interview, to generate other explanations and associations. For example, in his earlier interaction with the sound informational text, Bobby had learned that low sounds are caused by slow moving sound waves and he used this information to explain why the students hears a low sound when making sound with the long popsicle stick. He also explained that the student heard a high sound with the short thumb plucker because "you're plucking it fast," an idea that he stated while reading the sound informational text.

Plants informational text. For the plants informational text, 64% of the total idea statements Bobby generated were inferences. However, these inferences were relatively evenly divided across all three types with slightly more associations (nine of the 36 statements) and predictions (eight of the 36 statements) than explanations (six of the 36 statements), similar to the overall pattern in the whole data set. He elaborated on various information in the text, for instance, talking about how you can crack open an acorn ("smash it"), where the seeds grow (on the branches), what a shoot is ("tiny shoot is maybe a seed"), and what the acorns need to grow (water); and describing features of the flowers ("flowers have the seeds in them"). Bobby also made numerous predictions in response to the last part of the text; these predictions focused on ideas about what would happen to the flowers ("beginning of acorns") and acorns ("falls to the ground" and "make more oak trees"). He also tried to explain what causes the acorns to fall off the tree ("heat is warming it up"), why the shoot pushes into the ground (so the plant can grow), and why the leaves and plant grow (rain falls down; to make new acorns). The other 25% of the idea statements he produced while interacting with this text were paraphrases. Similar to the other texts, the inferences Bobby generated while reading this text relied heavily upon activating his background knowledge, accounting for more than 50% of his inferences. Similar to the sound informational text, Bobby reported a couple of visualizations, picturing the "acorn sprouting up" into a tree and "the roots coming out of the plant."

While interacting with the plants informational text, Bobby relied upon many ideas mentioned in the prior knowledge interview to make inferences. He knew that the plant needs water to grow; that the roots starts to grow out of the seed; that a tree grows from a seed; that a plant has leaves, roots, and a stem; and that the plant continues to grow over time. Bobby used all of these ideas to generate different inferences as he read the plants informational text. For example, after reading that "an oak tree begins to grow," Bobby elaborated on the text and described what the oak tree would look like at that stage ("got its leaves, its roots, and its stem").

Plants data text. When reading the observations about the growth of a pumpkin plant, about 75% of the idea statements Bobby generated were inferences and most of these inferences (ten of 16) were associations. He provided multiple elaborations on text ideas; for instance, Bobby added information about what the plant needs to grow (water, food, and time), the function of the roots (to drink the water), the function of the stem (taking the water to the leaves or flowers), and what grows on the stem (leaves). Intermittently, Bobby produced explanations (e.g., why the seed breaks apart or why the roots grow bigger), and he made a couple predictions about what will happen to different plant parts (e.g., seed will "sink further down into the dirt"). Similar to other text interactions, Bobby made a few paraphrases and a couple of visualizations (e.g. picturing "pumpkins that are sitting there on the stem") while thinking aloud with the plants data text. Like the pattern for the other texts, most of these inferences (14 of the 16 inferences) were generated through activation of relevant background knowledge. Many of the elaborated ideas, or associations, Bobby made can be linked back to his responses in the prior knowledge interview, such as the idea that a plant needs water to grow and ideas about the functions of the roots and stem.

Comprehension: Strong Relationship to Prior Knowledge

Overall Bobby showed high levels of explicit and implicit text comprehension for all four texts, as assessed by the six comprehension questions following each reading. Out of twelve possible points, his overall comprehension scores were nine, ten, twelve, and ten points for the sound informational, sound data, plants informational, and plants data texts, respectively. A closer look at his actual answers reveals a strong connection between his prior knowledge and his answers to these comprehension questions.

Sound informational text. For the sound informational text, the first three questions asked Bobby to recall information about when objects make sound, what a sound wave is, and what kind of pitch sound can have. He had no difficulty stating that objects make sound when they vibrate and that sound can have a low or high pitch, both ideas he mentioned in his prior knowledge interview and generated inferences about while thinking aloud. However, when talking about what a sound wave is, he was unable to identify it as moving air; instead Bobby talked about how you can make a sound wave by clapping your hands, which was an idea that he had generated as an association while thinking aloud. This response is a description of how a sound wave is produced, rather than a model for how sound is made and travels through the air.

The last three comprehension questions required Bobby to put together pieces of information to answer correctly. He accurately described why a lion's roar is a low pitch ("because the air in its throat is vibrating slowly"), but did not know what causes a sound to make a loud volume. In his think aloud comments, after reading that "slow vibrations make low pitched sounds" and "a lion's roar is low," he merged these ideas to explain that a lion's roar is low because "it does it slow." However, after reading that "big sound waves make louder sounds" and "loud sounds vibrate more air than quiet sounds," Bobby stated that he was "not thinking anything at the moment." Neither of the ideas about pitch and volume was present in his prior knowledge interview responses. The final comprehension question asked him to explain how we hear a beating drum from across the room. Bobby accurately answered this question, stating that "the sound wave comes out…goes in your ear and your ear drums and you can hear it." In both his prior knowledge interview and his think aloud comments, we find references to ideas about how sound is made and how it travels.

Overall the only difference noticed between Bobby's responses to the prior knowledge and comprehension questions is related to his understanding of low pitched sounds (comprehension question four). It could be that generating an explanation to integrate this information during reading supported Bobby in developing his understanding of the mechanism for creating low pitched sounds, while the absence of this when reading about what causes loud sounds to have a loud volume resulted in no changes in his understanding. Table 6.1 shows a comparison between Bobby's understanding of the main sound concepts from the prior knowledge interview and comprehension questions for both sound texts.

Sound data text. Bobby had no difficulty recalling that you see a rubber band moving up and down to make sound or you hear a ruler slapping against the wood to make sound. However, he was unable to talk about what you feel when the thumb plucker makes sound. When we look at his think aloud comments, we see that after reading about what the student felt with the thumb plucker, Bobby commented that "I

Table 6.1. Comparison of Bobby's Level of Understanding Before (Prior Knowledge Interview) and After (Comprehension Questions) Reading Sound Texts

	Sound Informational Text		Sound Data Text	
Performance Expectations	Prior Knowledge Questions (before reading)	Comprehension Questions (after reading)	Prior Knowledge Questions (before reading)	Comprehension Questions (after reading)
Identify situations when sound is and is not made	Adequate understanding	Adequate understanding	Adequate understanding	Adequate understanding
Explain how sound is made	Adequate understanding	Adequate understanding	Adequate understanding	Adequate understanding
Explain how you hear sound	Adequate understanding	Adequate understanding	Adequate understanding	Adequate understanding
Identify and explain how to change the volume – softer	Limited understanding	Not addressed in questions	Limited understanding	Not addressed in questions
Identify and explain how to change the volume – louder	Partial understanding	Partial understanding	Partial understanding	Not addressed in questions
Identify and explain how to change the pitch – higher	Partial understanding	Partial understanding	Partial understanding	Partial understanding
Identify and explain how to change the pitch – lower	Partial understanding	Adequate understanding	Partial understanding	Partial understanding

don't know that one." However, he generated different explanations after reading about the rubber band shaking and the ruler slapping the table, which might explain why this information was more easily recalled.

Bobby also answered all the implicit comprehension questions correctly. He knew that you needed to make an object vibrate in order for it to make sound, that sounds can have different pitches, and that you can hear a ruler from across the room "because it's slapping the table and making a big sound wave…and you can hear it because it goes into your ear." It is possible that Bobby might have been able to correctly answer these questions without even reading this text; all of these ideas were present and accurate in his prior knowledge interview (see Table 7.1). It might be that these implicit comprehension questions were less dependent on the text ideas and more closely aligned with students' everyday experiences (at least the first two implicit questions), which is one possibility for why we see ceiling effects.

Plants informational text. Bobby received full credit for his answers to all the comprehension questions about the plants informational text. He correctly recalled that the acorns grow on the branches, the acorn cracks open and grows roots and a stem after dropping to the ground, and the sprout gets bigger and grows leaves. In addition, he made the connections that the flowers are the beginning of the acorn, that the acorns need to fall off the tree to make more oak trees, and the seed grows the oak tree. Many of these ideas appeared in the inferences he generated while reading this text, for example, explaining why the seed breaks apart, describing features of different plant parts, and discussing what happens to the acorn and the flowers at different points in time. Many of these same ideas were also present in his prior knowledge interview responses.

Bobby showed growth in understanding the function of the seed and the flower after reading this text. Many of the text ideas addressed the acorn or seed, and Bobby commented on many of those ideas while thinking aloud. He provided associations about where the acorns grow and about cracking them open, talked about visualizing the acorn growing on the branches, and made predictions about what would happen to the acorns once they grew on the branches. However, it is important to mention that Bobby might have known about the seed and its function prior to reading, but since he never mentioned the seed during the prior knowledge interview, I did not probe his understanding about this plant part. While reading about the flowers, Bobby predicted that they were the "start of the acorns" and then later mentioned that the "flowers are what the acorns really are." In his response to the comprehension questions, Bobby demonstrated his understanding of the connection between the flowers and acorns, just as he did while reading the plants informational text. Table 6.2 shows how Bobby's understanding of the main plants concepts compared across the prior knowledge interview and comprehension questions for both plant texts.

Plants data text. For the plants data text, Bobby correctly recalled the main stages in the pumpkin plant's life cycle and that the roots of the pumpkin plant grow bigger over time and that the stem gets wider and thicker. He also was able to explain that the seed breaks apart "for the stem to get out" and the pumpkin plant grows flowers in order to be able to grow the pumpkin. However, Bobby was unable to explain why the

Table 6.2. Comparison of Bobby's Level of Understanding Before (Prior Knowledge Interview) and After (Comprehension Questions) Reading Plants Texts

	Sound Informational Text		Sound Data Text	
Performance Expectations	Prior Knowledge Questions (before reading)	Comprehension Questions (after reading)	Performance Expectations	Prior Knowledge Questions (before reading)
Identify examples of plants and non-plants	Adequate understanding	Not addressed in questions	Adequate understanding	Not addressed in questions
Identify root and its role	Adequate understanding	Not addressed in questions	Adequate understanding	Partial understanding
Identify stem and its role	Adequate understanding	Not addressed in questions	Adequate understanding	Not addressed in questions
Identify leaves and their role	Partial understanding	Not addressed in questions	Partial understanding	Not addressed in questions
Identify flowers and their role	Partial understanding	Adequate understanding	Partial understanding	Adequate understanding
Identify fruit and its role	Limited understanding	Not addressed in questions	Limited understanding	Not addressed in questions
Identify seeds and their role	Limited understanding	Adequate understanding	Limited understanding	Adequate understanding

Table 6.2 (cont'd).

	Sound Informational Text		Sound Data Text	
Performance Expectations	Prior Knowledge Questions (before reading)	Comprehension Questions (after reading)	Performance Expectations	Prior Knowledge Questions (before reading)
Identify air and its role in plant growth	Limited understanding	Not addressed in questions	Limited understanding	Not addressed in questions
Identify light and its role in plant growth	Partial understanding	Not addressed in questions	Partial understanding	Not addressed in questions
Identify water and its role in plant growth	Partial understanding	Not addressed in questions	Partial understanding	Not addressed in questions
Identify nutrients and its role in plant growth	Limited understanding	Not addressed in questions	Limited understanding	Not addressed in questions
Identify space and its role in plant growth	Limited understanding	Not addressed in questions	Limited understanding	Not addressed in questions
Identify stages in life cycle of plant	Adequate understanding	Adequate understanding	Adequate understanding	Adequate understanding

roots grow into the ground, which was surprising considering that he had mentioned that the roots get water for the plant in his prior knowledge interview and had talked about the pumpkin plant's roots "getting water" and "drinking…like a person" while thinking aloud. When reviewing his think aloud comments, we see that Bobby had made many associations and that some of the content of these associations matched the focus of the comprehension questions (although this was not always the case). For example, he produced explanations about why the seed breaks apart and about the function of different plant parts, ideas which might have been used to facilitate his comprehension of text ideas.

Summary and Discussion

One important feature of Bobby's responses to texts revolves around the strategies Bobby used to comprehend these texts. Overwhelmingly he generated a variety of inferences while reading these texts, but the types of inferences that dominated his interactions with each text differed. Bobby generated mainly associations with the sound informational text, explanations with the sound data text, predictions and associations with the plants informational text, and associations with the plants data text. These same patterns in students' text interactions can be found across the whole data set. It may be that particular text features, some related to the nature of the science content represented in each text, may help to explain some of these interactions. For example, the sound data text provided observations about three real world objects making sound, which might have prompted Bobby (and other students) to explain what caused these objects to move in particular ways. In addition, the temporal organization coupled with the lack of headings in the plants informational text might have cued Bobby (and other students) into thinking about the next steps in the process and stating his ideas about them.

Another important pattern is that Bobby draws upon his background knowledge and uses it as a source of inference generation; we see evidence of this for all four texts, although this relationship is more limited for the sound data text. While interacting with the sound data text, Bobby did draw upon his background knowledge, but some of these ideas were never discussed in the prior knowledge interview. This relationship between inference generation and prior knowledge, specifically students who generate more inferences are more likely to have higher levels of topic-specific prior knowledge, can be seen in Bobby's text interactions.

The last critical feature relates to the connection between prior knowledge and comprehension. Across all these texts Bobby's comprehension was quite strong with scores ranging between 75 to 100% accuracy. For all the texts, it appears that his prior knowledge contributed greatly to these results; in addition, many of the ideas from his prior knowledge were used to generate inferences. Specifically, many of the same ideas were part of his prior knowledge and the focus of his inference generation and he drew upon these sources to answer the comprehension questions. Across the whole data set, the trend across all texts was that students with higher prior knowledge tended to generate more inferences as well as comprehend better (although there was some variability in overall, explicit, and implicit comprehension). However, the relationship between the comprehension scores and students' inference generation was only significant for explanations on the sound informational text. In the next chapter, I return to these results and propose a theoretical model to explain these findings.

Chapter 7: Understanding Students' Processing and Comprehension of Science Texts: The Interplay of Student and Text Characteristics

There is a critical need in elementary instruction to incorporate informational texts in the classroom and help students make sense out of these texts. Duke (2004) advances this argument, stating that:

> Incorporating informational text in the early years of school has the potential to increase student motivation, build important comprehension skills, and lay the groundwork for students to grow into confident, purposeful readers (p. 3).

In the elementary classroom informational texts are most often used in connection to discipline area instruction. Both science and literacy educators have pushed for incorporating informational texts within science instruction. Particularly, they argue that informational texts can be used to address language arts and science instructional goals simultaneously, which can benefit students' science and literacy learning and their motivation and engagement in both areas. Science educators also strongly push for the use of scientific data in elementary classrooms to develop students' scientific literacy; their argument is that students need to work with data in order to more fully develop their understanding of scientific concepts as well as their understanding of the nature of science. However, the field lacks an understanding of what elementary students do with these different subject-specific texts and how their text interactions relate to their comprehension. This study was an attempt to address this research gap and build on current studies that examine the genre-specific nature of students' strategy use and reading comprehension and the role of texts in science instruction.

In this chapter I discuss the study's main findings. I begin by proposing a revised conceptual model to show the complex relationships between the reader, text, activity (defined as strategy use in this study), and comprehension suggested by the findings. I use this model as a springboard to: 1) consider particular text characteristics related to students' strategy use and 2) discuss how prior knowledge and particular inference types are related to students' comprehension. I end by discussing implications for the role of text in science instruction, the study's limitations, and suggestions for future research.

The Complex Nature of Student and Text Characteristics, Strategy Use, and Comprehension

Findings show that a multifaceted set of relationships exists between text characteristics, students' prior knowledge, strategy use, and comprehension. In this section, I unpack these findings and discuss factors that may be impacting students' interactions and comprehension with the texts in this study. In particular, I leverage a model of reading comprehension that focuses on the interaction of three key elements – reader, text, and activity – all set within a sociocultural context (Snow & Sweet, 2003) to explain the study's findings. I contend that we need to pay close attention to the specific features of all three elements when considering how students engage with subject-specific texts and what this means for helping students better comprehend these texts. In particular, I argue that we need to more closely attend to more nuanced text features related to the nature of the science content to understand how we can help students successfully comprehend the text's main ideas.

In chapter two, I presented a conceptual model detailing the relationships between various individual and text characteristics, students' strategy use, and comprehension.

Based on the findings from this study, I revised this conceptual model to more fully accommodate what I see as the complex interactions among these various components. Figure 7.1 displays this revised conceptual model.

As this model shows, it is not a one-way street from student and text characteristics to students' strategy use to their comprehension. Instead, all of these components interact with one another as well as students' comprehension. Findings from this study revealed three specific patterns: 1) students used various strategies, particularly different types of inferences, when reading the science informational and data texts across two topics, 2) students' prior knowledge is related to inference generation and comprehension (students relied extensively on their prior knowledge to generate inferences and students' prior knowledge significantly predicts their comprehension) and 3) explanations are the only inference type that relates to students' comprehension and this relationship occurred only for one text (sound informational). The first pattern is related to students' processing of these science texts, while the last two patterns concern students' comprehension of the four science texts. I discuss and explain each pattern in turn.

Students' processing of science texts: Moving beyond genre. As discussed earlier, some researchers have argued for more explicit attention to text genre, defined in terms of the structural features of texts, during cognitive strategy instruction in the content areas. However, findings from this study show that differences in student-text interaction patterns for science informational and data texts go beyond this simple distinction of genre, or text type. We need to look at the details of what these texts ask

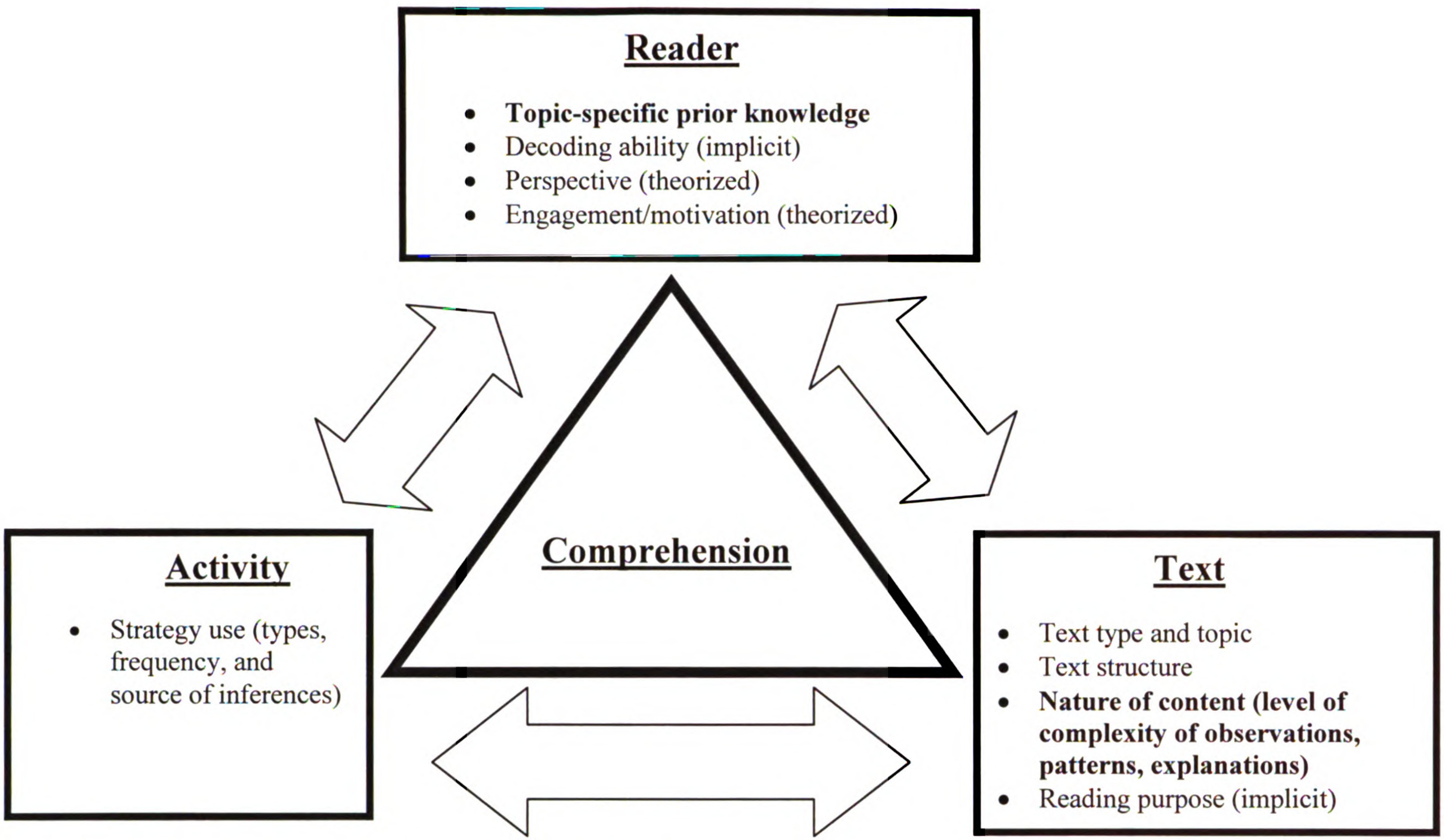


Figure 7.1. Revised conceptual model for the relationship between reader and text characteristics, students' strategy use, and comprehension

students to consider in terms of scientific ideas and how the science content is organized and structured; otherwise, we might miss important information that helps us understand what students do with these texts and why particular strategies are more strongly related to their comprehension.

Findings from this study support the idea that students' strategy use is context dependent. That is, students tend to use strategies with more or less frequency across text types and topics, even within one content area. Particular text characteristics, some stemming from the text type, others from the science topic or the way the science concepts are represented in the texts, point to possible explanations for these findings.

Students did generate more explanations for the data texts, but this result was driven by the large number of explanations students produced while reading the sound data text. I suggest three possibilities for why students tended to generate more explanations while reading the sound data text. One idea relates to how the science data is structured within each data text, while another idea connects to the availability of tools in the sociocultural context. The third idea stems from the presentation of science content within each text.

One key difference between the sound and plants data texts comes from the actual content of the observations. The sound data text provides observations detailing what the student saw, heard, and felt while making sound using three different sound systems – a thumb plucker, a rubber band strummer, and a ruler on the edge of a table. In contrast, the plants data text provides observations of what one object – a pumpkin plant – looks like as it grows from a seed to a fully grown plant. By providing similar observations across different objects, students might be better positioned to consider the patterns across these observations and generate explanations to explain these patterns (e.g., different objects can make louder sounds because more force is applied) in the sound data text. However, when reading observations about the growth of a pumpkin plant, the text does not explicitly prompt students to consider the growth of other plants, thus thoughts about patterns in data and explanations to explain these patterns were likely not on the students' minds. It may be that students need to be given multiple experiences with related phenomena to begin explaining the patterns and reasons behind these patterns in the data.

Many studies have documented how students use evidence to generate or evaluate explanations, and findings show students' abilities to do so vary considerably; students need support in identifying patterns and explaining the reasons for these patterns in real-world phenomena (Berland & Reiser, 2009; Chi, et al., 1994; McNeill, 2009; McNeill, Lizotte, Krajcik, & Marx, 2006). In order to successfully identify patterns in data and explain the reasons for these patterns, one criterion seems to be related to the actual data under consideration and the importance of having multiple pieces of data at a person's disposal. For example, some researchers have explored how elementary students develop causal explanations when working with experimental evidence and found that students can generate valid inferences using multiple pieces of evidence across several experiments (Kuhn, et al., 1992; Schauble, 1996). In these studies, there is explicit attention given to the need for several pieces of evidence in order to generate and consider scientific explanations or theories. In this study, on average, students generated more explanations when reading the sound data text compared to the other three texts; one feature of the sound data text was that it contained observations on three different sound systems, and these observations were similar in nature (e.g., what one saw, heard, and felt when making sound with each sound system). Thus, this text feature might be related to why students generated a greater number of explanations with the sound data text; students could more easily compare observations across objects.

Another key difference between the sound data text and the other three texts is the availability of real world tools. Prior to reading the sound data text, I showed students the actual sound systems and modeled how to make sound using each one. While reading, these sound systems sat on the table in front of the students, and could be accessed and referred to during reading. In fact, some students did point to specific objects during reading, with a few even attempting to replicate the observations they just read about. I asked them to wait until we finished reading all the texts to do so. However, for the other three texts, there were no objects in front of them, which might have made the actual phenomena feel less tangible to students. Many of the explanations the students produced while reading the sound data text talked about the reason for particular observations (e.g. why a student heard the ruler slapping the table or what caused the rubber band to move from side to side), and students might have used the objects in front of them to consider what would cause this observation (and others like it), for example, what one would have to do to a specific object to make it behave in a particular way.

Making sense of data is one critical aspect of inquiry, frequently identified as the hallmark of inquiry-based science instruction (National Research Council, 2008). The assumption is that students must interact with data in order to develop their conceptual understanding. This interaction can occur through firsthand data, which students collect themselves, or secondhand data, which is provided to students for analysis purposes. In this study, both data texts are examples of secondhand data; however, by showing students the actual sound systems and having them available for view might have evoked different reactions. These tools make have acted as "scaffolds" that supported students in visualizing and thinking about what caused particular observations.

Finally, the informational texts tended to present information in an objective manner. In reading the informational texts, students might have been less likely to interpret or contradict this information and, instead, to accept it at face value due to its presentation. In addition, especially in the sound informational text, the author actually provided explanations (e.g., why sounds make different pitches and volumes), thus reducing the need for students to do so while reading.

As predicted, students did generate more associations while reading the informational texts; however, this finding was attributed to the differences in associations for the sound text, not the plants text. One possible reason for the higher frequency with which students produced associations when reading the sound informational text is the more abstract and less concrete nature of the text ideas. For this text, the explanations for patterns in data are implied in the text. These explanations target students' model-based reasoning of intangible processes (e.g., the role of vibrations in creating sound), thus students might have a more difficult time understanding these ideas. This difficulty might prompt students to think of ideas related to these concepts, rather than generating explanations or predictions. Although the plants informational text also states information in a "generalizing," more objective way, the ideas are much less abstract because the text tells about the stages in an oak tree's life cycle and does not provide explanations for what causes the growth of particular plant parts.

For both topics students generated more predictions for the informational texts, but this difference was much more pronounced for the plants texts. One possible reason for this finding is that students had a more difficult time knowing what information was coming next in the informational texts. However, in the data texts, the organization of the observations in a chart format with headings that indicated upcoming content helped students know what to expect next. Maybe this text feature actually prompted students to refrain from making predictions because they already thought the text made it clear what was coming next – and therefore made it less necessary to think about this aspect of the text content during reading. Also, students were more likely to make predictions across the plants texts; this is not surprising considering that both of the plants texts were organized temporally versus a more descriptive organization for the sound texts. A temporal organization seems more likely to prompt students to consider the next steps in a process.

One important consideration is that classifying texts into genres not always as straightforward as it appears (Phillips, Smith, and Norris, 2000). In classifying these texts into genres, I relied upon a definition that focuses on how information is presented, with an emphasis on particular linguistic and form features (Dewdney, VanEss-Dykema, & MacMillan, 2001). Both informational texts provided descriptive information about scientific phenomena – how sound is made or how an oak tree grows – and used timeless verb construction, specialized, technical vocabulary, and a "generalizing" quality to the writing. On the other hand, the data texts stated actual observations of real-world phenomena, and these observations were written in first person and presented in a chart with headings to organize the data. In this sense, I originally categorized these texts – the informational and data texts – into two genre categories based on particular features, but findings suggest that a more complex view of genre better explains the results.

The problem with defining genre. In determining genre, others have used more refined categories than what I used here. For example, Donovan and Smolkin (2001) divide the genre of informational texts into two subcategories – nonnarrative and narrative. The main distinction between these two text types relates to the global organization for how the science topic is presented. Nonnarrative informational texts present a variety of subtopics and provide a description of attributes or facts to elaborate upon each subtopic. However, narrative informational texts present the information in a sequence and tell about the characteristics events in a process. From this perspective, the two informational texts in this study may be seen as two distinct types of informational texts – one nonnarrative (sound informational text) and the other narrative (plants informational text). Likewise, the data texts may also be considered using this distinction as well. The sound data text has a structure that is more reminiscent of a nonnarrative style – each part gives an observation related to what was seen, heard, or felt. – while the plants informational text presents observations of the pumpkin plant over time – more like the sequential nature of the narrative informational text. However, even distinguishing between the texts in this way still does not explain these patterns in students' text interactions. This distinction would suggest that you would see patterns more evenly divided across topics, which we do not. Instead the findings show that

students' text interactions are best understood by considering text type, topic, and features related to the science content and the way it is presented within the texts.

Using the notion of genre to refer to a kind or type of text has a long rooted history (Berkenkotter & Huckin, 1993; Chandler, 1997; Chapman, 1999; Langer, 1985). The classification of texts into groupings based on textual features, or properties, historically has been one of the most typical ways used to define genres. In his review of the concept of genre and genre approaches, Hyland (2002) posits that "all theories of genre rest on notions that groups of texts are similar or different, that texts can be classified as one genre or another" (p. 118). It is with these ideas in mind that I selected the science texts used in this study. That is, I leveraged off my own experience as an elementary school teacher as well as past research in reading and science to determine what written science texts educators might draw upon to develop elementary students' scientific literacy. Two kinds – what I refer to as informational and data texts in this study – came to the forefront. It is important to note that in my study I used the terms genre and text type synonymously to refer to texts that had similar structural and linguistic features, however, others have argued that these constructs can also be distinct (Paltridge, 1986).

In choosing texts that represented these two "genres," or text types, I focused on particular text features at the exclusion of other ones. Particularly, when selecting the texts, I zeroed in on features related to each text's form or structure. The informational texts were both written using a "generalizing quality," used timeless verb construction, and described information about scientific topics using relevant facts. In addition, the function, or purpose, of these two texts was to inform the reader about events in the natural world (e.g., how sound is made or how an oak tree grows). The function of the data texts was also to inform the reader about real world events, but these texts did so by reporting secondhand observations of scientific phenomena. The data texts were written in first person, organized in a chart format with clarifying headings, and used minimal content-related vocabulary.

I hypothesized that by conducting a textual analysis of what I assumed was the key features of these texts I could easily categorize them in order to make claims about how students interact with science texts. However, in this study, the science content within each text, how it was represented, and the context or situation for students' text interactions also played important roles in understanding what strategies students used during reading and how their strategy use related to their text comprehension. Specifically, these findings suggests that there is much complexity inside of science texts and this complexity indicates that treating any text as representative of one particular genre can be problematic.

A more nuanced conception of genre. Chapman (1999) provides a more nuanced view of genre by suggesting that genres go beyond typical structural text features and instead "reflect an integration of content (what we want to express), form (ways of organizing our words and ideas), function (purposes for writing), and context of situation (the setting, which is multidimensional and includes a range of factors from global to specific)" (p.470). For example, one of the texts – what I referred to as the sound informational text – included more complex scientific ideas. These ideas targeted patterns in the scientific phenomena as well as explanations for these patterns; they were more complex because their level of abstraction was increased. That is, to understand these patterns and explanations students had to visualize invisible processes (e.g., what sound waves are, how they travel in the air, how the properties of sound waves change and how that affects what you hear). However, in the other three texts, the science content was represented using mainly observations, which are statements that provide information on processes that students could envision (e.g. the stages in the life cycle of an oak tree or pumpkin plant, what you do to different objects in order to make sound and change the volume and pitch). In this way, we can think about the science content and how it is represented in these texts one feature of genre that serves as a "tool for thinking and communicating rather than its textual features" (Chapman, 1999, p. 483).

As shown above, text type and topic interact in complex ways and to some extent can be used to understand students' text interactions. The findings in this study suggest that we need to look beyond simple genre classifications in terms of structural features of texts and consider a more complex view of genre, one which addresses how the science content is represented in order to understand what students do with these texts. A closer look at the facilitative role of students' prior knowledge and the nature of the science content in each text can help us better understand students' comprehension of these science texts.

Students' comprehension of science texts: Bringing prior knowledge and the nature of the science content to the forefront. In this study, I predicted that students would be more likely to generate inferences if they had more prior knowledge on a topic and that these same students would also show better comprehension of text ideas. I also expected that students who generated a greater number of inferences while reading a particular text would also show higher comprehension scores for that text.

The facilitative role of prior knowledge in inference generation and comprehension. Findings showed moderate correlations between students' prior knowledge and text comprehension. For all four texts, prior knowledge was a significant predictor of students' overall comprehension scores. The linear regression models showed that students' prior knowledge accounted for 16.5% to 31.1% of the variance in students' comprehension, depending on the text. Qualitative analysis of patterns in students' prior knowledge interviews and their responses to the comprehension questions showed evidence that students demonstrated understanding of similar concepts in the prior knowledge interview and comprehension questions, like in the case of Bobby – although it is important to note that the questions on each instrument did not align completely by concept (a point that I will return to later). This finding regarding the facilitative role of prior knowledge in comprehension is well supported in the literature (Afflerbach, 1990; Carr, 1991; Gilabert, et al., 2005; Hirsch, 2003; Kintsch, 1988; Pearson, et al., 1979; Recht & Leslie, 1988).

When analyzing the source, or origin, for students' inferences, overwhelmingly students activated their background knowledge to generate explanations, predictions, and associations. However, findings showed a statistically significant but weak correlation for all four texts between students' prior knowledge and inference generation as well as between students' inference generation and overall, explicit, and/or implicit comprehension. One possible reason for these findings may be that students do rely extensively on their prior knowledge to make inferences, but the prior knowledge interviews only tapped into some of their topic-specific knowledge.

In addition, a closer look at specific strategies (e.g. explanations, predictions, associations) revealed the same results, although these statistically significantly but weak correlations only occurred for particular strategies on particular texts. Most perplexing was the finding that only one inference type – explanations – significantly predicted students' comprehension above and beyond the effect of prior knowledge and this relationship only occurred for one of the texts – the sound informational text. In the next section I explore reasons for this finding in more detail.

Examining complexity in the nature of the science content. In order to better understand why explanations are related to students' comprehension for the sound informational text but not the other texts, I suggest that a more thorough examination of the nature of the science content in each text is needed. By nature of the content, I mean the level of complexity of text ideas related to the science topic, which I define using a model of scientific activity.

Relating the complexity of experiences/observations, patterns, and explanations to students' comprehension. Anderson (2003) proposed a model, called the Experiences – Patterns – Explanations triangle, to represent two scientific practices – inquiry and application. Figure 7.2 provides a visual display of this model. At the bottom of the triangle, there are a multitude of experiences in the natural world that are used to identify a handful of patterns, which are in turn explained by a few scientific theories (e.g., theory of natural selection). The experiences consist of observations/interactions with real-world phenomena, while the patterns are laws or generalizations developed from the experiences. Experiences serve as the evidence to support the patterns and explanations.

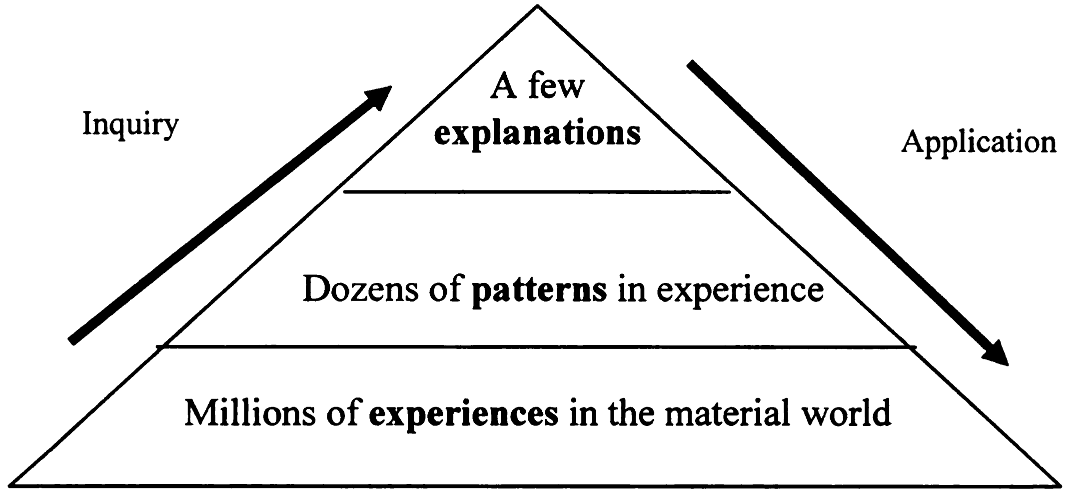


Figure 7.2. Experiences – patterns – explanations model

Clear differences emerge when examining the nature of the content in the four texts through the lens of experiences/observations, patterns, and explanations. The sound informational text is dominated mainly by patterns and explanations. Patterns discussed explicitly in this text include: "objects make sound when they move," "sounds can have a high or low pitch," "sounds have different volumes," and "sounds are louder when they are close." In addition, a few explanations are provided for these patterns. The text explains that when objects move the air vibrates, which creates sound waves that travel to your ear; this information provides a model that explains why objects make sound when they move and how you hear the sound. In addition, the sound informational text provides explanations for why sounds are different pitches and why loud sounds have a loud volume (e.g., "loud sounds vibrate more air than quiet sounds"). Interspersed among these patterns and explanations are a handful of experiences that illustrate or support these patterns and explanations; for example, the text discusses how "beating a drum vibrates the air" and gives examples of animals that make different pitched sounds.

In contrast, in the other three texts there is a focus on experiences/observations, but no explicit mention of any patterns or explanations. Like the sound informational text, the plants informational text presents facts about scientific phenomenon – in this case the growth of an oak tree. However, the text details the actual steps in each stage, explicitly describing what happens at that point. For example, when describing the first stage of growth (seed), the text describes how the acorn drops on the ground, cracks open, and a tiny shoot begins growing out of it. Likewise, the text describes how the sprout "pushes up from the acorn" and "unfolds into tiny leaves." The plants informational text never discusses how these stages are similar to the growth cycle of other plants, which would imply that these stages are patterns in the way that plants grow, and never provides explanations for why these particular plant parts grow and develop over time.

Both data texts provide observations of real-world phenomena. In the sound data text, the patterns are implied, but are not stated explicitly while in the plants data text no patterns or explanations are present or even implied. The sound data text provides observations of what one student heard, saw, and felt when making sound using a thumb plucker, rubber band strummer, and ruler on edge of table. Patterns in the data are implied; that is, in all the situations something moves to make sound, changing the length of the thumb plucker or ruler changes the pitch you hear, and changing the force that you use to pluck/push each item changes the volume. The plants data text provides observations of what happens to a pumpkin plant as it grows over time. In this text, no patterns or explanations are explicitly discussed; that is, students do not need to

understand or even necessarily consider why these plant parts grow in a particular order to understand the main ideas in this text.

As Norris el al. (2008) note in their discussion of research findings related to students' reading of scientific texts:

> When the reading involves material that can be interpreted in isolation – facts about what was observed or done, statements about the future (tense is a give away) – then they perform fairly well. When the reading requires integrating information from different parts of the text and seeing the connections between them, they perform significantly less well (p. 769).

In terms of this study, findings showed that students who generate more explanations when reading the sound informational text comprehend the text better; explanations explained more of the variance in students' comprehension above and beyond prior knowledge, but only for the sound informational text. A closer examination of the nature of the science content within each text in terms of how it represents experiences/observations, patterns, or explanations points to a possible explanation for this result.

As discussed above, the sound informational text suggests explanations that address causal, mechanistic reasons for how sound is made and why sound changes pitch and volume. To understand the main ideas, students are required to integrate multiple pieces of information from the text. However, in the other texts much of the material can be interpreted with minimal integration. Students can interpret the individual observations (e.g., the different stages of plant growth and what happens at each stage, what happens to each item as it makes sound) without elaborate integration across text ideas. For example, students can understand that the roots grow, followed by the stem and leaves, without any understanding of how the individual parts grow or why they grow in this order.

When developing the comprehension questions, I relied upon the explicit and implicit information in each text; that is, the questions clearly targeted ideas prompted or addressed by particular texts. Since the sound informational text includes both explicit and implicit information about scientific patterns and observations, the comprehension questions targeted these ideas (e.g. When do objects make sounds? Why is a lion's roar a low pitch? Why do loud sounds have a high volume?). In the other texts, the ideas presented focused mainly on observable phenomena and implied patterns. For this reason, most of the comprehension questions addressed these observable phenomena and implied patterns (e.g., What happens to the roots of the pumpkin plant over time? Why does the oak tree grow flowers? How are sounds different from each other?).

In order to answer the comprehension questions for the sound informational text successfully, students had to rely on different strategies. In particular, for the sound informational text, it was the students who generated explanations while reading who were more likely to understand these ideas. As we saw in Bobby's case, he generated explanations to integrate the ideas about the low pitch of the lion's roar and the idea that slow vibrations make low pitches, and he was able to successfully answer the question that targeted this implied information addressing causal, mechanistic reasons for this phenomenon. I argue that differences in the nature of the content – defined as the level of complexity of text ideas in terms of how they represent the three types of scientific practice (experiences/observations, patterns, and explanations) – can help us think more carefully about what it is these texts might help students to do in terms of developing their scientific understanding and what strategies are more and less useful for comprehending different science texts.

It is important to note that other researchers have conducted content analyses of informational texts and considered three main features related to the complexity of text ideas – lexical density, informational ideas, and textual content relationships (Donovan & Smolkin, 2001). In the next section, I will describe these approaches in more detail and discuss why they are inadequate to explain the findings in this study.

Relating lexical density, informational ideas, and textual content relationships to students' comprehension. In their content analysis of various science texts, Donovan and Smolkin (2001) focused on three important features – lexical density, informational ideas, and the textual content relationships. They argue that attention to each of these content features is important because they can impact how students comprehend science texts. Lexical density refers to how frequently content words are used across a particular text passage and can be measured by determining the average number of content related words used per clause (Halliday, 1993). For example, the sentence, "Acorns grow on oak tree branches," contains five lexical items – acorns, grow, oak, tree, and branches. These lexical items can be nouns, verbs, or any other content related words that appear in the text. Informational ideas relate to the amount of information, both explicit and implicit, contained in a particular clause and are calculated by determining the number of ideas within each clause and then computing an average across the whole text. Using the same sentence from above, there are two informational ideas contained in that sentence; the first idea is that acorns grow and the second idea is about where they grow (on oak tree branches). Finally, an analysis of textual content relationships refers to the hierarchical relationships among the content ideas in the text and examines the depth and breadth of text ideas. For example, in analyzing the textual content relationship between the content ideas in the plants informational text, the text organizes information by detailing a sequence of characteristic events. I found that there were seven subtopics, each detailing a stage in the oak tree's life cycle (e.g., seed/acorn, shoot, sprout) and that each subtopic was elaborated upon with one to three additional ideas. Donovan and Smolkin (2001) found that increases in the density of lexical or content related items in a text, in the average number of informational ideas per clause, and in the depth (number of topics and subtopics) and breadth (extent of elaboration) of content ideas leads to increased difficulty in reading and understanding the text. Table 7.1 shows results from an analysis of each text's lexical density, informational ideas, and textual content relationships.

Table 7.1. Lexical Density, Informational Ideas, and Textual Content Relationships across Four Texts

Text	Lexical Density (per clause)	Informational Ideas (per clause)	Textual Content Relationships
Sound Informational	4.3	1.6	3 subtopics 5 descriptive attributes (each elaborated with 1 to 3 ideas)
Sound Data	6.6	2.0	3 subtopics (each elaborated with 5 to 7 ideas)
Plants Informational	3.9	1.8	7 subtopics (each elaborated with 1 to 3 ideas)
Plants Data	5.1	2.1	6 subtopics (each elaborated with 1 to 3 ideas)

In examining lexical density it appears that students would have the most difficulty comprehending the ideas in the sound data text. However, for this text we found that on average students' overall comprehension was quite high (9.81 out of 12 total points). Likewise, the four texts in this study had similar averages for the number of informational ideas per clause; this proxy suggests that there are little differences in the complexity of the text ideas and, therefore, we would expect to see similar interactions across all four texts. In exploring the textual content relationships, we see that both plants texts appear to have more breadth (larger number of subtopics presented), but that the sound texts show more depth because they contain more elaborated ideas. From this analysis, it is unclear exactly what we would expect to see with regards to students' comprehension of these texts.

These conceptualizations of the complexity related to the nature of the content do not go far enough in helping us understand student-text interactions and their potential relationship to text comprehension with these subject-specific texts. Instead, I argue that this fourth conceptualization of the nature of the content – the level of complexity in relation to the observations, patterns, and explanations present in each text – is needed to better understanding the findings. In addition, none of these aforementioned ways to analyze the nature of the content address how the content represents specific scientific activities. For these reasons, I proposed a different dimension to better understand these findings.

Summary. As Chandler (1997) notes: "defining genres may not initially seem particularly problematic but it should…be apparent that it is a theoretical minefield" (p. 2). Chandler discusses how texts are sometimes categorized by "family resemblances" but it is unusual for any one text to contain all the textual features of a particular grouping; that is, one text could be a member of various genres depending on the text's particular form, function, content, and context (Chandler, 1997; Chapman, 1995, 1999). For example, an expository text written about the life cycle of a butterfly and told in a narrative format could be placed into various text groupings [e.g. grouped with other books: 1) written about life cycles of living objects, 2) written in a narrative format, 3) focused on the topic – butterflies, or 4) expository in nature]. One way to categorize texts, which I did not consider in my original definition of text genre, is related to the level of complexity of science ideas as defined using the Experiences – Patterns – Explanations model.

In order to be able to make recommendations for what types of strategies should be the focus of our instruction, we should have evidence that particular strategies make a difference in important outcomes, such as students' comprehension. Findings from this study suggest that it might be important for teachers to help students generate explanations while reading science texts that are more complex in terms of how the science content is represented. Of course this begs the question: Why are scientific explanations important?

Findings from this study suggest that the strategy of generating explanations helps students comprehend more complex science texts. Other research supports this contention. Chi et al. (1989) found that students who generate more self-explanations while solving physics problems showed a better understanding of the underlying principles. They describe how explanations can support various functions including:

> ...refine and expand the conditions of an action, explicate the consequences of an action, provide a goal for a set of actions, relate the consequences of one action to another, and explain the meaning of a set of quantitative expressions (p. 175).

Thus, students "relate their actions to the principles and concepts in the text, which in turn further enhances their understanding of principles" (p. 176). So, when students generate explanations, they are more likely to be connecting important pieces of information together that address the underlying scientific model or theory and this, in turn, supports the development of their conceptual understanding.

Findings from this study suggest that different strategies might be more (or less) useful for comprehending different science texts; that different strategies might be better for addressing particular instructional goals; and that students' prior knowledge is implicated in these relationships. Essentially, findings suggest that context matters for both how students interact with different types of science texts and how they comprehend these texts. When choosing texts, teachers need to understand and attend to specific text features, especially features related to the nature of the science content. I accounted for and examined some of these individual and text features in this study, but we need to consider additional factors in future research on students' comprehension of subject-specific texts. In the next section of this chapter, I discuss implications, specify limitations of this research study, and detail recommendations for future research to extend our understanding of how elementary students interact with and comprehend science texts.

Implications

Findings from this study provide empirical evidence to show that students use different strategies to comprehend science specific texts and that these patterns in students' text interaction go beyond typical genre distinctions. Findings show that only one inference type (explanations) is related to higher comprehension scores and this only occurs for one of the texts (sound informational). Taken together, these findings suggest that researchers and educators need to move towards a more complex view of genre and pay closer attention to other text features, in particular the level of complexity with which science content is represented within these texts, in order to understand what students do with these subject-specific texts and how that is related their comprehension.

Different science texts vary in the degree to which three features of scientific activity – experiences/observations, patterns, and explanations – are made explicit or implicit. It should not be a surprise to science researchers or educators that students do not necessarily consider patterns or explanations when interacting with data. That is, we should not expect students to independently think about patterns and explanations in data when given a set of observations. Instead, students need to be directed to attend to these more complex features of scientific activity, which can be accomplished either through specific text features or by using instructional scaffolds and teacher support.

Many researchers have argued in support of the need for strategy instruction tailored to particular text types (Norris, et al., 2008). Findings from this study suggest that this recommendation should be taken seriously. Particular texts might be better suited to addressing specific instructional goals and students can use different strategies to meet these goals. For example, if we want students to consider why certain patterns exist, we need to use texts that go beyond experiences and observations to discuss the underlying model-based reasoning for phenomena or we need to provide other supports to move students' thinking in this direction. This is also where one type of inference -

explanations - come into play; explanations help us consider the causal reasons or mechanisms to understand real-world phenomena and help us integrate complex ideas together.

Another particularly important finding from this study focuses on the major influence of topic-specific knowledge and experiences in relationship to students' inference generation and comprehension. This finding suggests how important it is for educators to ensure they provide abundant and rich experiences in the classroom for students to learn about real-world phenomena. These experiences can serve as springboards for students to begin building their initial understandings about phenomena in the natural and social world, and they can use these ideas to help them understand scientific ideas and observations presented in different science texts. This message is especially important and timely considering that elementary classrooms have seen a decrease in the amount of instructional time in science and social studies, mainly due to the pressure from NCLB and the focus on language arts and mathematics instruction. If we continue this overemphasis on these subject areas, then we are unlikely to see any substantial changes in students' facility when reading and comprehending different subject-specific texts. It is clear that topic-specific prior knowledge predicts students' comprehension on science texts, and limiting opportunities to build students' topic-specific knowledge seems in direct opposition to developing students' scientific literacy.

The final implication relates to how educators consider the role of text in science. Reading and comprehending science texts are complex tasks that require attention to a myriad of factors that likely influence these processes. It is imperative that elementary teachers recognize this complexity and go beyond seeing reading as merely a tool to promote science goals, the derived sense of scientific literacy, but also view the importance of science literacy in its fundamental sense where students are able to read and write using science texts (Hand, et al., 2003; Norris, et al., 2008; Phillips & Norris, 2009). In my literature review, not once did I see research from the reading field that mentioned data as a type of text. I think that this is an important and unfortunate oversight in the reading community. We need to better understand how students interact with and understand both informational and data texts, especially in science where firsthand and secondhand data is so vital to developing students' conceptual understanding.

Limitations

One of the major limitations from this study is related to my selection and categorization of the four texts. In this study, I matched the science texts based on genre, or text type (informational or data texts) and did so by attending to specific structural features of these texts. For example, when choosing science informational texts, I sought to find texts that presented scientific information in a "generalizing" way, used timeless verb construction, and addressed concepts important to that topic. Likewise, when selecting the data texts, I made sure that they presented observations of scientific phenomena in an organized fashion; these observations were written in first person and presented using a table with headings. However, findings suggest some of these features help us to understand students' text interactions but other features of the text, particularly the complexity of the nature of the science content and how it is represented within each text, might be equally or more important for understanding the relationship between students' text interactions and comprehension. In my analysis of the nature of the science content, I found that only one text – the sound informational text – explicitly and implicitly went beyond experiences/observations and addressed scientific patterns and explanations. From this perspective, it could be argued that the other three texts were not cognitively challenging enough so students did not need to generate any particular inference type in order to impact their comprehension. Findings from this study can be used to design future research that more thoroughly explores some of these additional text features. In particular, studies could examine students' interactions with science texts that vary in terms of the level of complexity, as identified by the Experiences – Patterns – Explanations framework, for how the science content is represented.

The next limitation is closely related to the first one. In this study, I developed the prior knowledge interview questions by identifying concepts for each topic from state and national standards. However, I developed the comprehension questions by examining each text and determining the various explicit and implicit ideas within each text. By using different questions before and after reading, it was difficult to determine exactly how students' conceptual understanding changed, if at all, as a result of their text interactions. In addition, since the comprehension questions were text-dependent, this meant they were not matched across texts (besides the more global categories of explicit and implicit) and this feature limits what I can say about the relationship between students' text interactions and comprehension across texts. I am unable to compare individual student's comprehension across texts (e.g., comparing whether students comprehend particular texts better) due to this limiting feature in the research design.

Another limitation stems from the fact that there is still a large amount of variability in students' comprehension that is unaccounted for in the model. A limitation of this study is the lack of attention given to additional factors that may relate to students' text interactions and comprehension. Other factors, such as readers' interest and engagement with texts in general and science texts in particular, as well as their view of the purposes of reading and science, might also impact these outcomes. Research has shown that students who are more engaged, or interested, in what they are reading or more motivated to read a particular text may comprehend the text better (Baker, Dreher, & Guthrie, 2000; Guthrie, et al., 1998; Guthrie, Wigfield, Barbosa, et al., 2004; Guthrie, Wigfield, & Perencevich, 2004). Other research has revealed that students' views of reading and science can vary and that these factors may be implicated in the relationship between the reader, activity, text, and comprehension. Even though I set a similar reading purpose for each text (e.g., to learn information about how sound is made or how a particular plant grows in order to explain these ideas to a friend), students may have had different views on the overall purpose for reading, which might have influenced how they interacted and comprehended these texts. These views go beyond whether the specific purpose is for entertainment or study purposes and instead focus on what it means to engage in the act of reading itself. For example, some students might consider the goal of reading any text to be accurate word recognition and ability to locate information in a text. This reading goal, called the "simple view of reading," differs from the view of reading as inquiry or "principled interpretation of text" where a reader "infers meaning by integrating text information with relevant background knowledge" (Norris, et al., 2008, p. 770). It is possible that students' reading behavior will vary in response to this perspective, such that students who see reading as a straightforward process of recognizing words and locating information might be more likely to use particular strategies and/or show different comprehension profiles.

In a similar vein, students may have different ideas about the nature of science and these views may influence how they interact with the science informational and data texts. Much work has been conducted detailing students' conceptions of the nature of science (Lederman, 1992). Sandoval (2003) succinctly captured the major distinctions in opposing views regarding the nature of science – on one side of the continuum is students who view science as "a process of building models and testing theories," while on the other side students see "science…as a steady accumulation of facts about the world" (p. 11). This difference in viewing science knowledge as either constructed or transmitted might help to account for patterns we see in students' text interactions and their comprehension of the text ideas. Students who view science knowledge as tentative and socially constructed may be more likely to engage in explanation building and identifying patterns in the data; they might see these activities as important to the construction of scientific knowledge and consider them an integral part of what it means to do science. It would be important to explore these factors in additional studies of students' interactions with science texts in order to build a more comprehensive understanding of these complex relationships. It remains to be seen how these variables might account for student-text interactions and comprehension.

A fourth limitation in this study is that I did not use standardized reading tests to assess students' decoding and comprehension abilities. Instead, I relied upon teacher recommendations to ensure students were reading on or above grade level. I did so because I trusted that teachers have a good understanding of individual students' strengths and weaknesses in reading and have multiple data sources to rely upon when making this judgment (e.g., daily informal observations, formal district and state reading assessments). However, the teachers in this study taught in various schools across multiple school districts. It is possible that the schools and districts may vary in their criteria for below, average, and above grade level readers. In this study, none of the students appeared to have any difficultly with decoding the written words, although comprehension difficulties can be harder to ascertain.

A final limitation relates to the use of think aloud methodology to capture students' cognitive processing of these texts. The assumption is that students will report what they are consciously thinking about as they read texts. However, being aware of your conscious processing of a text and being able to talk about what you are thinking are two separate processes that can be difficult for young students. In addition, students' verbal ability may play a role in how successfully they engage in this process. More verbal students may have an easier time reporting their thoughts during reading. Another possibility is that students may consider some thoughts so obvious that they refrain from stating them, even though they have been encouraged to tell everything they are thinking during reading, or they may generate comments that are not thoughts they would have had in the absence of being asked to engage in the think aloud process.

Future Research

Past research shows that we need better answers about how students learn with different types of text, especially subject-specific texts. Although the findings from this study point to the complex relationships between reader and text characteristics, students' strategy use, and their comprehension, further research is needed to better understand the interactions among these various parts, especially when investigating students' reading and comprehension of science texts. One of the most important implications from this study is that we need to go beyond differences in text genre to help explain students' text interactions and comprehension when reading science texts. In particular, findings point to one particular line of inquiry that would be fruitful: more in-depth exploration of how the science content is represented within different types of science texts in terms of experiences/observations, patterns, and explanations and how this variation relates to students' strategy use and comprehension. This examination could include further testing of the theory that the strategy of generating explanations is related to students' comprehension of more conceptually complex science texts. The use of additional science informational and data texts that vary in terms of the level of complexity in the nature of the science content are needed in future studies.

Another related line of research could examine teachers' views of and use of different science texts in classrooms. Currently we have an idea of reasons elementary teachers draw upon when selecting informational science texts for instructional use and how they use these informational science texts in practice (Donovan & Smolkin, 2001; Pappas, Varelas, Barry, & Rife, 2004; Varelas & Pappas, 2006), but there is limited research on what elementary teachers do when they have students interact with firsthand as well as secondhand data in the classroom or what criteria or resources they draw upon when deciding what data to use and how to use it in practice.

Finally, as mentioned earlier, this study did not account for other factors that have been shown to relate to students' reading comprehension, such as engagement/motivation and students' perspective on the purpose for reading or science. Additional studies of students' reading and comprehension of science texts can include attention to these other factors. Likewise, we want to make sure that all students – not just average and above average readers – are able to successfully comprehend different types of science texts. Extending this research to include all types of readers, as well as younger and older elementary students, will help us better understand the complex relationships between the reader, text, activity, and his/her comprehension of science texts.

Conclusion

Findings from this study revealed that students' text interactions are related to the structural features of the text, the written content and how it is presented, and the sociocultural context in which the reading event occurs. These findings support this idea that conceptions of genre need to go beyond simple distinctions in text type, or structure, and include attention to the written content, the purpose of the written text, and the setting in which the reading event occurs. We need to consider the features of these other parts in order to develop a more thorough understanding of how students make sense of science texts and what we can do to help them successfully comprehend these texts. This more nuance view suggests that attention should be given to how theses genres are used in the social world and "the ways in which genre is embedded in the communicative activities of a discipline" (Berkenkotter & Huckin, 1993, p. 476). Thus, especially in science, what the content is and how it is represented is so important to building students' understanding. Studies that ignore the variability within the representation of the content, differences in students' topic-specific prior knowledge, and the context of the situation, especially when considering students' comprehension of subject-specific texts, will be missing important factors that can help explain how students reason with and understand these science texts.

In conclusion, findings from this study allow us to see how certain features, namely the science content and the context for students' think alouds, are important for understanding the variability in students' text interactions within the science discipline. An important challenge in successfully improving students' comprehension is determining the different features of these science texts and which features matter in terms of understanding students' strategy use and comprehension. Research needs to delve deeper into understanding the variability in science texts, especially since, to date, much of this variability has gone unexplored in research studies that have examined the nature of students' strategy use with subject-specific texts. Such research will enable teachers and policy makers to make more effective decisions that help students successfully comprehend science texts as well as build their literacy skills and scientific understanding.

APPENDICES

APPENDIX A

Prior Knowledge Interview (Sound)

<u>Content Standards</u>

Michigan's K-7 Grade Level Content Expectations (Michigan Department of Education, 2007)

- Physical Science, Energy (P.EN.03.31): Relate sounds to their sources of vibration
- Physical Science, Energy (P.EN.03.32): Distinguish the effect of fast or slow vibrations as pitch

National Science Education Standards (National Research Council, 1996)

- Position and Motion of Objects, K-4: Sound is produced by vibrating objects. The pitch of the sound can be varied by changing the rate of vibration (p. 127).

Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993)

- Motion, K-2: Things that make sound vibrate (p. 89).

At the elementary level, the main concepts for this topic focus on how sounds are made and the properties of sound (pitch and loudness). Specifically, key concepts involve recognizing the role of vibration in producing sound and how the pitch and volume of sound can be changed.

<u>Interview Questions</u>

1. Ask the student to determine whether or not a sound is made (not whether you would hear the sound or not) in the following situations: person hitting a drum, watching a violin sitting on a table, birds flapping their wings, person bouncing a ball, rocking chair sitting still on floor. Ask for some other examples for each category.
2. How is sound made? What do you need to make a sound?
3. Show student rubber band box instrument and ask student to make a sound using the instrument. What part of the instrument makes the sound?
4. How can you change the volume of the sound of the rubber band box instrument?
5. How can you change the pitch of the sound of the rubber band box instrument?

APPENDIX B

Prior Knowledge Interview (Plants)

Content Standards

Michigan's K-7 Grade Level Content Expectations (Michigan Department of Education, 2007)

- Life Science, Organization of Living Things (L.OL.02.14): Identify the needs of plants.
- Life Science, Organization of Living Things (L.OL.04.15): Describe that plants require air, water, light, and a source of energy and building material for growth and repair.
- Life Science, Organization of Living Things (L.OL.02.22): Describe the life cycle of familiar flowering plants including the following stages: seed, plant, flower, and fruit.
- Life Science, Organization of Living Things (L.OL.03.31): Describe the function of the following plant parts: flower, stem, root, and leaf.
- Life Science, Organization of Living Things (L.OL.03.41): Classify plants on the basis of observable physical characteristics (roots, leaves, stems, and flowers).

National Science Education Standards (National Research Council, 1996)

- The Characteristics of Organisms, K-4: Organisms have basic needs. For example, animals need air, water, and food; plants require air, water, nutrients, and light (p. 129).
- The Characteristics of Organisms, K-4: Each plant or animal has different structures that serve different functions in growth, survival, and reproduction (p. 129).
- Life Cycle of Organisms, K-4: Plants and animals have life cycles that include being born, developing into adults, reproducing, and eventually dying (p. 129).

Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993)

- Flow of Matter and Energy, K-2: Plants and animals both need to take in water and animals need to take in food. In addition, plants need light (p. 119).

At the elementary level, the main concepts for this topic focus on what organisms need to grow, commonalities regarding the parts of plants, the function or role these parts play in plant growth and development, and the stages in the life cycle of a plant.

Interview Questions

1. Ask the student to determine whether or not the following items are examples of plants: flower, tree, cow, dandelion, person. Ask for some other examples for each category. Ask student to explain why examples given are plants.
2. What are the parts of a plant? Ask student to describe how each part identified helps the plant.
3. What does a plant need to grow? Ask student to explain how each item identified helps the plant grow.

4. How does a plant (e.g., apple tree) change over time? (e.g., How does it start? What happens next?) Ask student to describe what happens at each stage.

APPENDIX C

Think Aloud Protocol Introduction

Demonstration Directions: Today you are going to read aloud some texts about plants and sound. When you read aloud these texts, I am going to have you stop and think aloud after you read each sentence. Thinking aloud as you read can help you understand the text better. When you stop and think aloud, I want you to tell me everything that you are thinking about what you just read. Before we read the texts about plants and sound, I want to show you what it looks like and sounds like to think aloud when reading texts. Then, I will give you a chance to practice thinking aloud with a different text before we begin.

Demonstration #1: I have a writing piece about sand and how sand is made. After I read each sentence, I will stop and think aloud. When I think aloud I will tell you everything that I am thinking about what I just read. I put the word **STOP** at the end of each sentence to remind me to stop and think aloud. Let me show you how to stop and think aloud as you read a text.

Sand is many tiny pieces of rock. **STOP** Wind blows on rock. **STOP**
Rain falls on rocks. **STOP** Waves crash on rocks. **STOP** The wind, rain, and waves break the rocks into tiny pieces. **STOP** The rocks become sand. **STOP**
[Source: Sand by Margaret Clyne and Rachel Griffiths, p. 3-5]

Think Aloud Stop 1: A lot of little rocks put together make sand. Sand can go through my fingers.
Think Aloud Stop 2: The wind causes little pieces of rock to break off from big rocks. Waves can also bang into rocks to do this.
Think Aloud Stop 3: The rocks get wet.
Think Aloud Stop 4: The waves can hit the rocks hard and make little pieces of rock break off.
Think Aloud Stop 5: The rocks break into little pieces. It takes a long time for this to happen.
Think Aloud Stop 6: The rocks used to be big but they are tiny now. I made a little bit of sand once by hitting rocks together.

Demonstration #2: I have a writing piece about germs and how germs make you sick. After I read each sentence, I will stop and think aloud. When I think aloud I will tell you everything that I am thinking about what I just read. I put the word **STOP** at the end of each sentence to remind me to stop and think aloud. Let me show you how to stop and think aloud as you read a text.

Germs are tiny living things. **STOP** They are far too small to see with your eyes alone. **STOP** There are many different kinds of germs. **STOP** But the two that usually make you sick are bacteria and viruses. **STOP** Germs, such as bacteria and viruses, are found everywhere. **STOP** They are in the air you breathe, in the food you eat, in the water you drink, and on everything you touch. **STOP** They are even on your skin and in your body. **STOP** [Source: Germs Make Me Sick! By Melvin Berger, p. 6-8]

Think Aloud Stop 1: Germs are really small. They can sneak into our bodies without us noticing.
Think Aloud Stop 2: You probably need a microscope to see the germs.
Think Aloud Stop 3: There are good and bad germs.
Think Aloud Stop 4: You can get sick from the flu virus. I don't really know what bacteria is.
Think Aloud Stop 5: You can find them on things that you touch, like door knobs.
Think Aloud Stop 6: My parents always tell me to wash my hands a lot.
Think Aloud Stop 7: Germs, being too small to see, can be on your hands and fingers without you ever knowing they are there.

Practice Directions: Now, it is your turn to try thinking aloud as you read a new text. Remember, after reading each sentence, you will see the word **STOP** written in capital letters. When you see the word **STOP**, I want you to stop and think aloud. When you think aloud, I want you to tell me everything that you are thinking about what you just read.

Practice #1: This writing piece has information about earthworms and how they eat. You will read the writing piece so that you will be able to tell a friend how an earthworm eats. As you read, you will see the word STOP at the end of each sentence. When you see the word STOP, I want you to stop reading and tell me what you are thinking about what you just read. If you are not thinking anything at that moment, just continue reading. If you are thinking something about what you are reading and you do not see the word stop, you can still stop and tell me what you are thinking. You do not have to wait until you see the word stop to tell me what you are thinking about what you are reading. As you read, I want you to think about how an earthworm eats so that you would be able to tell a friend about how an earthworm eats.

Earthworms feed on the rotting parts of dead plants. **STOP** They have no teeth or jaws, so the food they eat has to be very soft. **STOP** Sometimes they nibble food with their tiny lips, but usually they suck it up. **STOP** In the daytime, worms usually stay under the soil and feed on the roots of dead plants. **STOP** At night, when it is dark and damp, they crawl up to the surface and search for dead leaves. **STOP** They drag the leaves under the ground. **STOP** [Source: Earthworms by Claire Llewellyn, p. 12-13]

Practice #2: This writing piece has information about butterflies and how they grow. You will read the writing piece so that you will be able to tell a friend how a butterfly grows. As you read, you will see the word STOP at the end of each sentence. When you see the word STOP, I want you to stop reading and tell me what you are thinking about what you just read. If you are not thinking anything at that moment, just continue reading. If you are thinking something about what you are reading and you do not see the word stop, you can still stop and tell me what you are thinking. You do not have to wait until you see the word stop to tell me what you are thinking about what you are reading.

As you read, I want you to think about how a butterfly grows so that you would be able to tell a friend about how a butterfly grows.

This butterfly lays her eggs on the leaves of a flower. **STOP** The eggs hatch into caterpillars. **STOP** The caterpillars eat the leaves and grow big and fat. **STOP** Slowly each one turns into a pupa. **STOP** Later, the pupa splits open and a new butterfly comes out. **STOP** [Source: Insects and Crawly Creatures by Angela Royston]

APPENDIX D

Informational Text - Sound

Directions: Today you are going to read aloud a writing piece that has information about sound and how sound is made. You will read the writing piece so that afterwards you will be able to tell a friend about how sound is made. As you read, you will see the word STOP at the end of each sentence. When you see the word STOP, I want you to stop reading and tell me what you are thinking about what you just read. If you are not thinking anything at that moment, just continue reading. If you are thinking something about what you are reading and you do not see the word stop, you can still stop and tell me what you are thinking. You do not have to wait until you see the word stop to tell me what you are thinking about what you are reading. Remember, you want to make sure to read carefully so that after reading you will be able to tell a friend about how sound is made.

Informational Text:

Objects make sounds when they move. **STOP**

Beating a drum vibrates the air. **STOP** The moving air is called a sound wave. **STOP** You hear sound when the wave enters your ear. **STOP**

Sounds can have a high or low pitch. **STOP** Fast vibrations make high-pitched sounds. **STOP** A bird chirps a high sound. **STOP** Air in its throat vibrates fast. **STOP**

Slow vibrations make low-pitched sounds. **STOP** A lion's roar is low. **STOP** The air in a lion's throat vibrates slowly. **STOP**

Sounds have different volumes. **STOP** A loud sound has a high volume. **STOP** Big sound waves make louder sounds. **STOP** Loud sounds vibrate more air than quiet sounds. **STOP**

Sounds are louder when they are close. **STOP** Sounds become quieter as sound waves travel farther away. **STOP**

[Source: Sound by Becky Olien]

APPENDIX E

Data Text – Sound

Directions: Today I have some science data to show you. Another student made observations about what they heard, saw, and felt when making sound using three different objects – a thumb plucker, a rubber band strummer, and a ruler placed on the edge of a table (point to each object). The student recorded his observations on a data chart. These observations can help you understand how sound is made. You will read the observations so that afterwards you will be able to tell a friend about how sound is made. As you read, you will see the word STOP at the end of each sentence. When you see the word STOP, I want you to stop reading and tell me what you are thinking about what you just read. If you are not thinking anything at that moment, just continue reading. If you are thinking something about what you are reading and you do not see the word stop, you can still stop and tell me what you are thinking. You do not have to wait until you see the word stop to tell me what you are thinking about what you are reading. Remember, you want to make sure to read carefully so that after reading you will be able to tell a friend about how sound is made.

Object	**What I See**	**What I Hear**	**What I Feel**
Thumb plucker	I see the popsicle stick moving up and down. **STOP**	I hear the popsicle stick hitting against the wood block. **STOP** When I pluck the long popsicle stick I hear a low sound. **STOP** When I pluck the short popsicle stick I hear a high sound. **STOP** When I push down hard on the long popsicle stick and let go I hear a loud sound. **STOP** When I push down gently on the long popsicle stick and let go I hear a soft sound. **STOP**	I feel the popsicle stick hitting the bottom of my thumb. **STOP**
Rubber band strummer	I see the rubber band shaking from side to side. **STOP**	I hear a hollow sound when the rubber band moves back and forth. **STOP** When I pluck the rubber band hard I hear a loud sound. **STOP** When I pluck the rubber band gently I hear a soft sound. **STOP**	I feel the rubber band tingle my fingers. **STOP**
Ruler on edge of table	I see one side of the ruler moving up and down really fast. **STOP**	I hear the ruler slapping the table. **STOP** When I put a long piece of the ruler hanging over the edge of the table and push down I hear a lower sound. **STOP** When I put a short piece of the ruler hanging over the edge of the table and push down I hear a higher sound. **STOP**	I feel the ruler shaking when I touch it. **STOP**

Appendix F

Informational Text - Plants

Directions: Today you are going to read aloud a writing piece about plants and how they grow. This writing piece has information about an oak tree and how it grows. You will read the book so that you will be able to tell a friend how an oak tree grows. As you read, you will see the word STOP at the end of each sentence. When you see the word STOP, I want you to stop reading and tell me what you are thinking about what you just read. If you are not thinking anything at that moment, just continue reading. If you are thinking something about what you are reading and you do not see the word stop, you can still stop and tell me what you are thinking. You do not have to wait until you see the word stop to tell me what you are thinking about what you are reading. Remember, you want to make sure to read carefully so that after reading you will be able to tell a friend about how an oak tree grows.

Informational Text:

Acorns grow on oak tree branches. **STOP** Acorns are the seeds of an oak tree. **STOP**

Acorns drop on the ground in the spring. **STOP** The acorn cracks open. **STOP** A tiny shoot pushes out of its hard shell. **STOP**

The shoot pushes itself into the ground. **STOP** A small sprout pushes up from the acorn. **STOP** A shoot becomes the root of the oak tree. **STOP** The sprout unfolds into tiny leaves. **STOP**

An oak tree begins to grow. **STOP** It is small and has a few leaves. **STOP** Many years pass before the tree grows tall. **STOP** The acorn is now an oak tree. **STOP**

Each spring the oak tree sprouts leaves. **STOP** These leaves grow on the branches. **STOP** Tiny flowers grow up next to the sprouting leaves. **STOP** The flowers help the tree make acorns. **STOP**

Acorns grow fat during the spring and summer. **STOP** Soon they will fall off the tree. **STOP**

[Source: From Acorn to Oak Tree by Jan Kotte]

APPENDIX G

Data Text – Plants

Directions: Today I have some data to show you about plants. Another student made observations about what they saw happening to a pumpkin plant as it grew over time. The student recorded his observations about what the pumpkin plant looks like at different times on a data chart (point to appropriate places on chart). These observations can help you understand how plants grow. You will read the observations so that afterwards you will be able to tell a friend how a pumpkin grows. As you read, you will see the word STOP at the end of each sentence. When you see the word STOP, I want you to stop reading and tell me what you are thinking about what you just read. If you are not thinking anything at that moment, just continue reading. If you are thinking something about what you are reading and you do not see the word stop, you can still stop and tell me what you are thinking. You do not have to wait until you see the word stop to tell me what you are thinking about what you are reading. Remember, you want to make sure to read carefully so that after reading you will be able to tell a friend about how a pumpkin plant grows.

Time	**What Plant Looks Like**
Day 1	I see a black and gray seed sitting in the dirt. **STOP** The seed is down into the ground. **STOP**
Day 7	The roots have grown into the ground. **STOP** The seed is starting to break apart a little bit. **STOP** I see a little green stem starting to grow out of the seed. **STOP**
Day 20	I see a green stem that has poked out of the soil and grown upward out of the dirt. **STOP** There are two leaves on the plant and the roots have grown much bigger. **STOP**
Day 30	I see some more leaves on the plant and the stem has grown longer and thicker. **STOP** The roots have grown much longer. **STOP**
Day 60	I see that the plant has flowers now. **STOP** The roots are longer, the stem is thicker, and the leaves got bigger. **STOP**
Day 90	I see small pumpkins where the flowers used to be. **STOP** I see the roots, stem, and leaves and they look the same. **STOP**
Day 120	I see big pumpkins that are ready to be harvested. **STOP** The roots, stem, and leaves of the plant look the same. **STOP**

APPENDIX H

Comprehension Questions

Informational Text – Sound

1. When do objects make sound? (explicit)
2. What is a sound wave? (explicit)
3. What kind of pitch can sound have? (explicit)
4. What causes a lion's roar to be a low pitch and not a high pitch? (implicit)
5. Why do loud sounds have a loud volume? (implicit)
6. How do we hear the beating drum from across the room? (implicit)

Data Text – Sound

1. What do you see when the rubber band strummer makes sound? (explicit)
2. When the ruler is making sound what do you hear? (explicit)
3. When you make sound using the thumb plucker, what do you feel? (explicit)
4. What has to happen for an object to make sound? (implicit)
5. How are sounds different from each other? (implicit)
6. How do we hear the ruler from across the room? (implicit)

Informational Text – Plants

1. Where on the oak tree do the acorns grow? (explicit)
2. What happens to the acorn after it drops to the ground? (explicit)
3. What happens to the sprout? (explicit)
4. Why does the oak tree grow flowers? (implicit)
5. Why is it important that acorns fall off the oak tree? (implicit)
6. Do you need a seed to make an oak tree? Why or why not? (implicit)

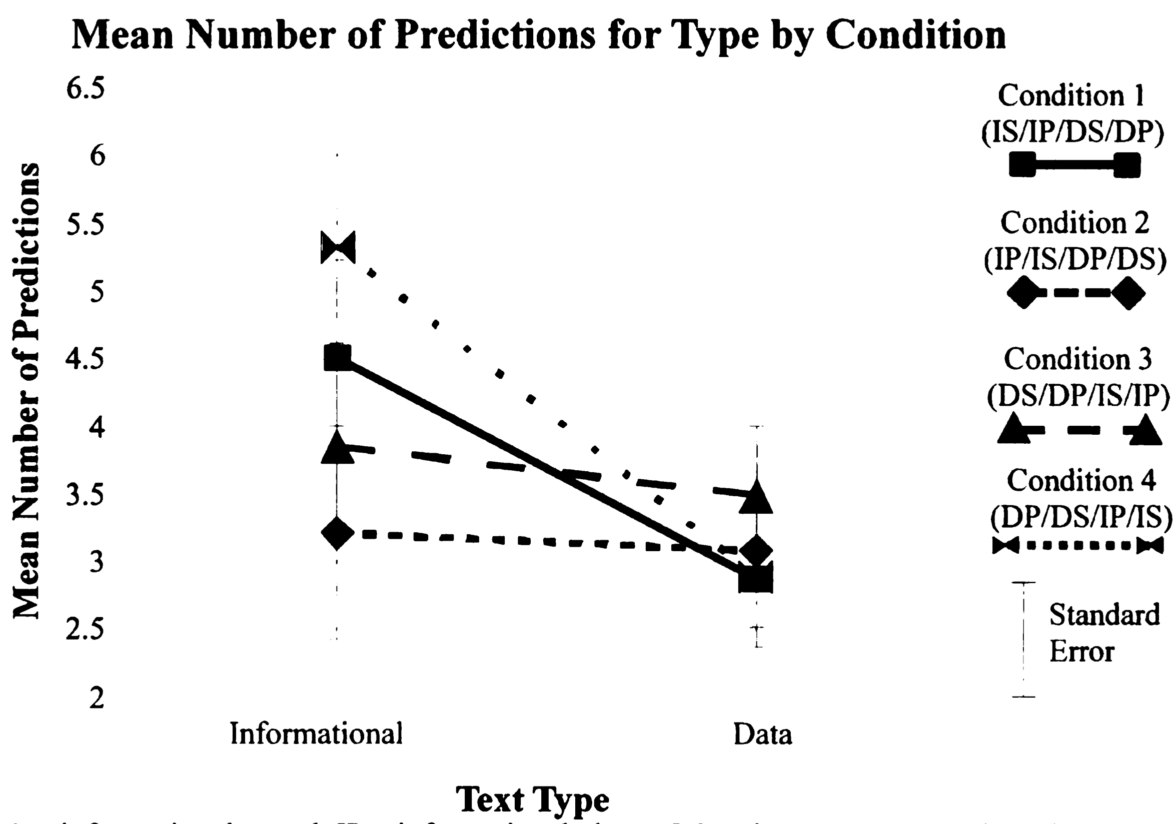
Data Text - Plants

1. What happens to the roots of the pumpkin plant over time? (explicit)
2. What happens to the stem as the pumpkin plant grows? (explicit)
3. What are the different stages of a pumpkin plant's life? (e.g., How does it start? What happens next?) (explicit)
4. Why does the seed break apart? (implicit)
5. Why do the roots grow into the ground? (implicit)
6. Why does the pumpkin plant grow flowers? (implicit)

APPENDIX I

Higher Order Effects for Mean Number of Predictions

The first higher order effect for mean number of predictions is for type by condition, $F(3, 76) = 3.000$, $p < .05$. In all four conditions, students made more predictions for the informational texts than for the data texts. This text type effect is most pronounced in condition four and is weaker in the other conditions. However, post hoc paired t-tests did not show significant differences between the mean number of predictions for informational and data texts in condition one [$t(19) = .433$, $p = .670$], condition two [$t(21) = -.469$, $p = .644$], condition three [$t(20) = 1.284$, $p < .214$], or condition four [$t(20) = 1.884$, $p = .074$]. The following figure provides a graphical display of the type effect by condition.



IS = informational sound; IP = informational plants; DS = data sound; DP = data plants

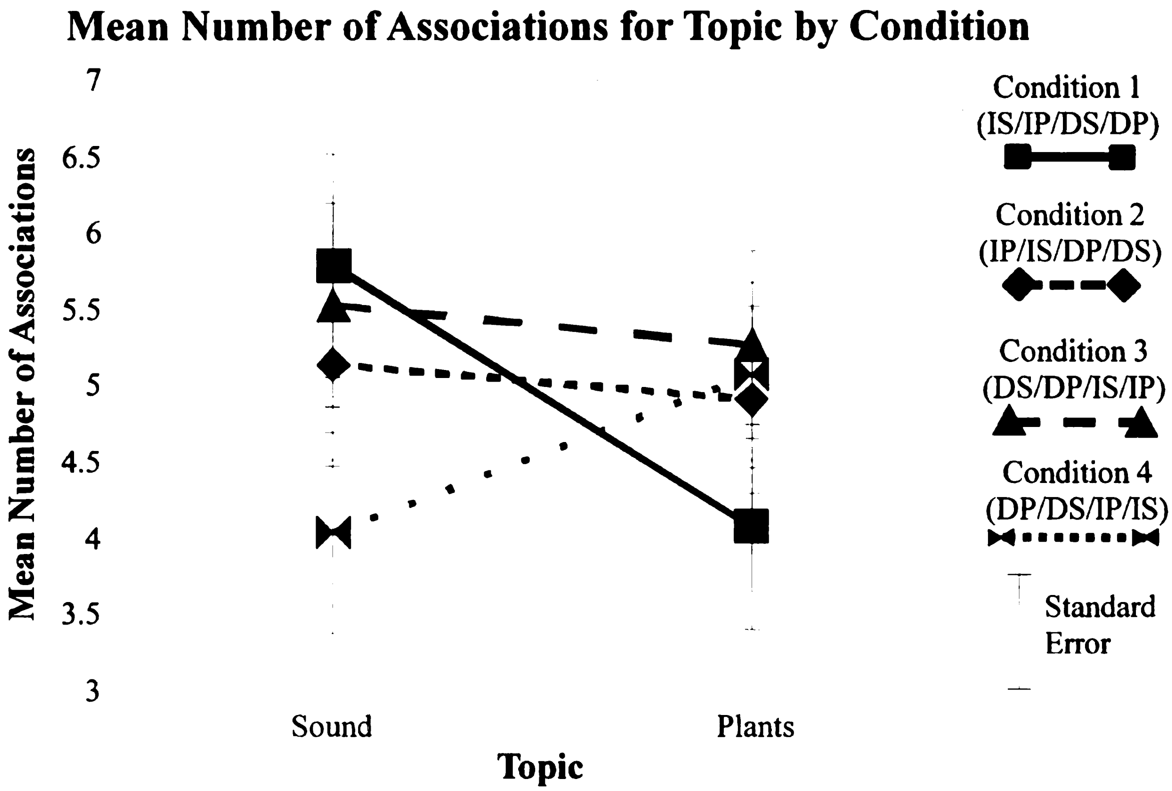
Maybe by starting with the plants data text, the text that has a well-structured temporal organization and headings, prompts students to begin thinking about upcoming steps or information in the text. Then, after they have experienced thinking aloud with two texts, they are better positioned to begin vocalizing their predictions with the other texts.

The second higher order effect related to the number of predictions students produced was for topic by type by gender, $F(1, 76) = 9.733$, $p < .01$. Females generated more predictions for the informational texts than the data texts within each topic; as well they generated more predictions for the plants topic than the sound topic. Males also generated more predictions for the plants topic than the sound topic across the informational texts. However, this pattern changed for males across the data texts – they made more predictions on the sound as compared to the plants text, although this difference was slight. Post-hoc tests showed significant differences between the mean number of predictions for females on the plants informational ($M=4.70$) and data text ($M=3.39$), [$t(43) =2.111$, $p < .05$], and between the sound informational ($M=3.64$) and data text ($M=2.75$), [$t(43) =2.083$, $p < .05$], and for males on the plants informational ($M=5.55$) and data text ($M=2.80$), [$t(39) = 4.702$, $p < .001$]. However, differences between the mean number of predictions for males on the sound informational ($M=3.05$) and data texts ($M=3.10$), [$t(39) = -.122$, $p = .904$] were not significant.

APPENDIX J

Higher Order Effects for Mean Number of Associations

There was one higher order interaction effect for mean number of associations, which was for topic by condition, $F(3, 76) = 2.863$, $p < .05$, for mean number of associations. The figure below shows a plot of topic by condition for associations produced.



IS = informational sound; IP = informational plants; DS = data sound; DP = data plants

These plots show that overall students made more associations for the sound topic in conditions one, two, and three. However, in the fourth condition the pattern is reversed: students made more associations for the plants texts than the sound texts. Also, the topic effect is most pronounced for students in condition one (e.g., the slope of the line is steeper than in the other conditions) and is less pronounced for conditions two and three. Post-hoc tests showed significant differences between the mean number of associations for students in condition one between the plants and sound texts, [$t(19) = -2.170$, $p < .05$], but not for students in condition two, [$t(20) = -.312$, $p = .758$], in condition three, [$t(21) = .334$, $p = .742$], or in condition four, [$t(20) = 1.522$, $p = .144$]. Maybe when students start by reading a text that addresses something they are familiar with, like the growth of a pumpkin plant, they are more likely to consider other pieces of information related to the text ideas across all texts for that topic.

APPENDIX K

Higher Order Effects for Mean Number of Paraphrases

The first higher order effect for mean number of paraphrases is for topic by type by condition, $F(1, 76) = 4.318$, $p < .05$. In examining the plots of this higher order effect, the graphs showed that students in conditions two, three, and four did not deviate too much from the overall pattern of topic by type. However, students in condition one made the greatest number of paraphrases for the sound data text (M=9.26), about the same number of paraphrases for the plants informational (M=7.96) and the plants data texts (M=7.46), and a much lower number of paraphrases for the sound informational text (M=4.27). Post-hoc tests showed significant differences in the mean number of paraphrases for students in condition one between the sound informational and data texts, [$t(19) =4.134$, $p = .001$], between the plants informational and sound informational texts, [$t(19)=3.449$, $p < .01$], and between the plants data and sound informational texts, [$t(19)=2.856$, $p =.04$]. However, there were no significant differences in the mean number of paraphrases for students in condition one between the plants informational and data texts, [$t(19) =.111$, $p = .912$], between the sound data and plants informational texts, [$t(19) =.769$, $p = .452$], or between the sound data and plants data texts, [$t(19) =.956$, $p = .351$].

The second higher order effect is for topic by type by gender, $F(3, 76) = 2.742$, $p < .05$. For the sound topic, both females and males made more paraphrases for the data texts than the informational texts. However, for the plants topic, females made a larger number of paraphrases for the informational text (M=7.56) than the data text (M=5.89), [$t(43)=3.112$, $p < .01$], while males made a similar number of paraphrases across these two texts [for plants informational ($M=7.96$) and for plants data ($M=7.24$); $t(39)=1.041$, $p = .304$]. At the moment, my theory for student-text interactions is not able to account for these differences.

APPENDIX L

Example Student Responses to Comprehension Questions for Sound Informational Text

Comprehension Question	Adequate Understanding (2 points)	Developing Understanding (1 point)	Limited Understanding (0 points)
Question 1[a]: When do objects make sound?	When something hits it that makes it vibrate and then makes a sound wave.	When they get hit against something. Like if wind blows on them they'll hit together like wind chimers.	Um, not sure.
Question 2[a]: What is a sound wave?	A sound wave is like a vibration that travels through air.	A sound wave is when you like talk and then the, um, the sound moves, um, keeps on moving to somebody's ear.	Um, like wind maybe or the sound of the thing that you're moving or hitting or.
Question 3[a]: What kind of pitch can sound have?	Sound can have high pitches and low pitches.	---	Pitch. Maybe I forgot. Not sure.

[a] Explicit questions

[b] Implicit questions

Comprehension Question	Adequate Understanding (2 points)	Developing Understanding (1 point)	Limited Understanding (0 points)
Question 4[b]: What causes a lion's roar to be a low pitch and not a high pitch?	The air in its throat is vibrating really slow so it makes a lower sound.	Um, it like its throat it doesn't vibrate that fast.	Um, if it's not so angry or anything it's not as loud.
Question 5 [b]: Why do loud sounds have a loud volume?	Because the sound waves are bigger and you can hear better and you talk louder.	Because they're closer.	Because they're more high pitch. Because the it goes more faster.
Question 6 [b]: How do we hear the beating drum from across the room?	Um, because like, um, if you, um, hit the drum it'll make a sound wave and vibrations so once the sound wave hits your ears you'd be able to hear it.	I think that wave likes comes over the room. This is a loud sound.	Cause drums are louder and you hit them hard. When you hit a drum harder they're very they're louder.

[a] Explicit questions
[b] Implicit questions

APPENDIX M

Example Student Responses to Comprehension Questions for Sound Data Text

Comprehension Question	Adequate Understanding (2 points)	Developing Understanding (1 point)	Limited Understanding (0 points)
Question 1 [a]: What do you see when the rubber band strummer makes sound?	Um, it goes up and down really fast. And the air is there and it's making sound waves out to every direction.	---	You see black stuff and it'll make a lower sound when you thump it it'll and like you'll see black spots and stuff. Black spots. You'll see black spots if it's dirty and you don't wash it off.
Question 2 [a]: When the ruler is making sound what do you hear?	Uh, a slapping like onto the table sound like the kid said in his observations.	---	I hear well you can't really hear anything. I don't.
Question 3 [a]: When you make sound using the thumb plucker what you do you hear?	Um, the, um, popsicle stick hitting the bottom of my thumb.	It feels weird. I've done that before and my whole thumb went numb for like two days.	I am not very sure.

[a] Explicit questions
[b] Implicit questions

Comprehension Question	Adequate Understanding (2 points)	Developing Understanding (1 point)	Limited Understanding (0 points)
Question 4 [b]: What has to happen for an object to make sound?	Um, it has to do something. It can't just stay there and doing do nothing. It has to actually move.	You have to do something. Like you have to flick it, stomp it.	Um, what has to happen, um, I don't know the answer to that.
Question 5 [b]: How are sounds different from each other?	Um, cause the harder you hit it it makes the sound change its volume. It'd be louder. If you hit it softer it wouldn't it wouldn't be as loud. It'd be quiet. They can be high or low.	I don't really know. Some of them have sound chambers. Some of them don't. They usually some of them have pressure on them. Some of them don't. Some of them have rubber bands. Some of them don't. Judging of what the main object is.	I don't really know that.
Question 6 [b]: How do we hear the ruler from across the room?	Because the ruler vibrates and it and it hits this so we can hear it. The vibrations come over and hit our ears. The sound waves come over and hit our ears when it's vibrating. It makes sound waves just pop out of it.	Um, I think the sound waves and I think the molecules it's just a loud sound from what they hit. A wave.	Well, like if you hit it really fast it makes a loud sound so you could hear it.

[a] Explicit questions

[b] Implicit questions

APPENDIX N

Example Student Responses to Comprehension Questions for Plants Informational Text

Comprehension Question	Adequate Understanding (2 points)	Developing Understanding (1 point)	Limited Understanding (0 points)
Question 1 [a]: Where on the oak tree do the acorns grow?	Acorns grow on branches a lot.	---	Um, on the maybe on the leaves or something.
Question 2 [a]: What happens to the acorn after it drops to the ground?	It cracks and a shoot comes out of it.	It be- it becomes a snack for the squirrels.	Um, it grows another leaves.
Question 3 [a]: What happens to the sprout?	Um, it becomes it becomes when it after a few it'll get like a trunk and a big branches and leaves	Um, it, um, first it turns into roots and then a little stem and then it grows little and then it grows branches. Then it grows a few leaves and then in a couple of years, um, it will, um, turn into a big tree.	The sprout pops and dives in the ground.

[a] Explicit questions

[b] Implicit questions

Comprehension Question	Adequate Understanding (2 points)	Developing Understanding (1 point)	Limited Understanding (0 points)
Question 4 [b]: Why does the oak tree grow flowers?	Because that's how they get the acorns to grow on them. So then we could have like the acorns and stuff.	Because, um, um, because like every tree it just doesn't like grow instantly it has, um, a little start. Yeah. Be- so, um, because, um, because you can't, um, just like go out and plant a acorn because it has to start out as something and, um, yeah.	So it can make cause so it can make, um, like food for it.
Question 5 [b]: Why is it important that acorns fall off the oak tree?	Because there would be no oak trees if the acorns didn't fall off	---	So if they can't climb the tree or if they're hurt they don't have to actually climb up the tree. It can they can just grab it when it falls. So that they can eat them if they don't know how to climb up.
Question 6 [b]: Do you need a seed to make an oak tree? Why or why not?	Yes. Because if there is no seed then then the oak tree won't grow.	Yes. Because it need if you don't put a seed it'll just die and like in one minute.	I'm not sure. Because, um, acorns are kind of like the seed and, um, I don't really know if it's a seed or not.

[a] Explicit questions
[b] Implicit questions

APPENDIX O

Example Student Responses to Comprehension Questions for Plants Data Text

Comprehension Question	Adequate Understanding (2 points)	Developing Understanding (1 point)	Limited Understanding (0 points)
Question 1 [a]: What happens to the roots of the pumpkin plant over time?	The roots grow bigger and also longer.	Oh, it just like it just grows.	It grows a stem on it.
Question 2 [a]: What happens to the stem as the pumpkin plant grows?	It gets thicker and taller and the leaves start to grow and then they get more and they get bigger.	---	The stem. I don't know that.
Question 3 [a]: What are the different stages of a pumpkin plant's life?	Um, mostly the seed. Roots. Then the stem. Then the leaves and flowers. Then little pumpkins. Then the big pumpkins. It's ready to be picked.	Um, a seed, the roots and the stem, and a big pumpkin. Goes from little to a big pumpkin.	Um, first we first it goes in like the orange first and then it goes on the stem and then then I don't know.

[a] Explicit questions

[b] Implicit questions

Comprehension Question	Adequate Understanding (2 points)	Developing Understanding (1 point)	Limited Understanding (0 points)
Question 4 [b]: Why does the seed break apart?	So the roots and stem can get out.	Because the water like pushes up against it and it goes into like this into like the inside of the seed and it well it just wears down the seed.	I have no idea.
Question 5 [b]: Why do the roots grow into the ground?	Um, because they need to go down and suck up water and bring it to the plant.	---	The roots grow into the ground because like you need it needs dirt to grow to grow. Like for the seed. Be- like because like in, um, just be- get dirt.
Question 6 [b]: Why does the pumpkin plant grow flowers?	So it can grow pumpkins.	Um, that's because that's part of its life cycle. Um, I'm not sure if it helps it in any way.	I'm not really sure.

[a] Explicit questions

[b] Implicit questions

APPENDIX P

Correlation Matrix of Comprehension Scores and Number of Different Think Aloud Comments for Sound Informational Text

Variables	1	2	3
1. Overall comprehension	---		
2. Explicit comprehension	.736**	---	
3. Implicit comprehension	.879**	.324**	---
4. Inferences	.306**	.318**	.204
5. Non-inferences	.087	.145	.020
6. Inaccurate ideas	.079	.021	.096
7. Explanations	.342**	.357**	.227*
8. Predictions	.183	.136	.159
9. Associations	.200	.241*	.109
10. Paraphrases	.186	.235*	.094
11. Metacomments	-.086	-.120	-.036
12. Personal connections	-.008	.027	-.020
13. Questions	-.161	-.120	-.141
14. Visualizations	.073	.036	.076
15. Personification	a	a	a
16. Incomprehensible	.049	.185	-.061

[a] Correlations could not be obtained., *p < .05, **p < .01

APPENDIX Q

Correlation Matrix of Comprehension Scores and Number of Different Think Aloud Comments for Sound Data Text

Variables	1	2	3
1. Overall comprehension	---		
2. Explicit comprehension	.738**	---	
3. Implicit comprehension	.892**	.354**	---
4. Inferences	.218*	.135	.212
5. Non-inferences	.141	.211	.054
6. Inaccurate ideas	.037	.049	.018
7. Explanations	.214	.186	.173
8. Predictions	-.033	-.096	.018
9. Associations	.185	.085	.200
10. Paraphrases	.081	.127	.027
11. Metacomments	.078	.094	.046
12. Personal connections	.078	.093	.046
13. Questions	-.065	-.100	-.023
14. Visualizations	.049	.065	.024
15. Personification	a	a	a
16. Incomprehensible	-.076	.036	-.130

[a] Correlations could not be obtained., *p < .05, **p < .01

APPENDIX R

Correlation Matrix of Comprehension Scores and Number of Different Think Aloud Comments for Plants Informational Text

Variables	1	2	3
1. Overall comprehension	---		
2. Explicit comprehension	.757**	---	
3. Implicit comprehension	.847**	.294**	---
4. Inferences	.179	.004	.258*
5. Non-inferences	.122	.102	.095
6. Inaccurate ideas	-.177	-.074	-.199
7. Explanations	.195	.133	.177
8. Predictions	.138	-.017	.216*
9. Associations	.044	-.071	.122
10. Paraphrases	. 214	.123	.213
11. Metacomments	-.139	-.067	-.149
12. Personal connections	-.027	.126	-.142
13. Questions	-.094	-.129	-.033
14. Visualizations	.121	.090	.104
15. Personification	-.150	-.159	-.090
16. Incomprehensible	-.109	.007	-.165

*p < .05, **p < .01

APPENDIX S

Correlation Matrix of Comprehension Scores and Number of Different Think Aloud Comments for Plants Data Text

Variables	1	2	3
1. Overall comprehension	---		
2. Explicit comprehension	.735**	---	
3. Implicit comprehension	.911**	.390**	---
4. Inferences	.312**	.236*	.281**
5. Non-inferences	.150	.083	.153
6. Inaccurate ideas	-.043	-.074	-.013
7. Explanations	.169	.075	.183
8. Predictions	.128	.129	.095
9. Associations	.326**	.263*	.283**
10. Paraphrases	.188	.192	.138
11. Metacomments	-.001	-.122	.073
12. Personal connections	.102	-.082	.188
13. Questions	-.050	-.021	-.056
14. Visualizations	-.124	.023	-.183
15. Personification	-.114	.014	-.163
16. Incomprehensible	-.267*	-.258*	-.205

*p < .05, **p < .01

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