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# 4. EXPLANATORY REASONING IN JUNIOR HIGH SCIENCE TEXTBOOKS

## INTRODUCTION

Current reforms in science education emphasize the importance of using inquiry-based teaching strategies that engage students in formulating explanations from evidence (National Research Council [NRC], 2000). Specifically, for example, the National Science Education Standards in the United States state that students in grades 5 to 8 should "develop descriptions, explanations, predictions, and models using evidence" and "think critically and logically to make the relationships between evidence and explanations" (NRC, 1996, p. 145). As an additional example, current science education curriculum documents in Alberta include outcomes that expect students to investigate, explain, interpret, and discuss evidence for scientific concepts. For example, the *Planet Earth* unit in Grade 7 includes outcomes such as "Investigate and interpret evidence that Earth's surface undergoes both gradual and sudden change" and "Interpret models that show a layered structure for Earth's interior; and describe, in general terms, evidence for such models" (Alberta Learning, 2003, p. 27).

Critiques of science education have suggested that science instruction often focuses on factual knowledge and on the processes of experimentation and data gathering, but deemphasizes the construction of meaning and argumentation (P. Newton, Driver, & Osborne, 1999). Furthermore, previous studies of curriculum resources—in particular laboratory activities—suggest that the activities provide students few opportunities to engage in posing questions, investigating natural phenomena, and formulating explanations from evidence (Germann, Haskins, & Auls, 1996; Tamir & Lunetta, 1981). This research seeks to determine what opportunities curricular resources provide for students to reason about explanations, where these opportunities occur, and what supports are provided for student reasoning about explanations.

## REASONING AND EXPLANATION IN CURRICULAR MATERIALS

Although teachers use a variety of sources when constructing the curriculum for their classroom, textbooks and associated curricular materials are often one of the largest drivers of curricular decisions (Woodward & Elliott, 1990). A national survey of science teachers in the U.S. found that 93% of grade 7–9 teachers used a published textbook and 45% of these teachers reported that they had students do seatwork assigned from the textbook and/or complete supplemental worksheets in

*Stephen P. Norris (Ed.), Reading for Evidence and Interpreting Visualizations in Mathematics and Science Education, 65–81.*

their most recent lesson (Weiss, 1987). Therefore, it is important to examine the ways in which textbooks and associated resources provide opportunities and support for students in regard to reasoning about explanations.

Previous studies have examined aspects of scientific reasoning and explanation in textbooks and associated curricular materials from a variety of perspectives. Studies have examined the ways textbooks engage students in scientific reasoning, including studies of themes related to scientific literacy (Chiappetta, Fillman, & Sethna, 1991; Chiappetta, Sethna, & Fillman, 1993; Lumpe & Beck, 1996), reasoning levels of textbook questions (Pizzini, Shepardson, & Abell, 1992), and aspects of inquiry in scientific laboratory manuals (Germann et al., 1996; Tamir & Lunetta, 1981). Text analyses have also examined how scientific explanations are presented in textbooks and science trade books (L.D. Newton, D.P. Newton, Blake, & Brown, 2002; Penney, Norris, Phillips, & Clark; 2003; Smolkin, McTigue, Donovan, & Coleman 2009).

Studies of how textbooks address scientific literacy provide insight into the emphasis that textbooks place on aspects of reasoning. Chiappetta et al. (1991) analyzed five science textbooks for themes related to scientific literacy. They categorized the text into four themes: (a) the knowledge of science, (b) the investigative nature of science, (c) science as a way of thinking, and (d) interaction of science, technology, and society. They found that the proportion of the textbook devoted to the investigative nature of science, in which the textbook actively stimulates thinking or doing, ranged from 1.9% to 39.4%, with the highest percentage of the textbook being devoted to the transmission of scientific knowledge. The investigative nature of science theme includes textbook material that requires students to: (a) answer questions, (b) make a calculation, (c) reason out an answer, or (d) engage in a thought experiment. Of the four themes of scientific literacy, the investigative nature of science theme is most likely to directly engage students in some sort of reasoning about scientific ideas. However, the nature of the reasoning cannot be directly determined from this analysis. Further analyses using these themes found that 22% to 46% of middle school life science textbooks and 11.6% to 36.2% of high school biology textbooks were devoted to the investigative nature of science (Chiappetta et al., 1993; Lumpe & Beck, 1996).

Even when textbooks actively engage students in answering questions, the reasoning required to answer questions is often at a fairly low cognitive level. Pizzini et al. (1992) analyzed eight middle school science textbooks and found that more than 78% of the questions in the textbooks were input level questions—questions that required students to recall information from memory or from the senses. The authors suggested that this focus on input level questions fails to develop higher order thinking skills and that questions should incorporate more opportunities for students to apply, analyze, synthesize, and evaluate information.

Science laboratory activities that are part of the textbook materials are an obvious place in the science curriculum to incorporate aspects of scientific reasoning. Tobin (1990) stated that "laboratory activities appeal as a way to learn with understanding and, at the same time, engage in a process of constructing knowledge by doing science" (p. 405). Tamir and Lunetta (1981) found that investigations in high school science laboratory manuals are often highly structured with few opportunities for students to formulate hypotheses, questions, and predictions, design investigations, and formulate new questions. Studies looking specifically at high school biology laboratory manuals found that the activities provided students opportunities to manipulate equipment and develop observational skills, though rarely engaged students in posing questions, solving problems, investigating natural phenomena, constructing answers, and making generalizations. Although the manuals often asked students to draw conclusions, they seldom asked students to provide evidence for those conclusions (Germann et al., 1996; Lumpe & Scharmann, 1991).

Examinations of the nature of scientific explanations in textbooks have also found limitations in how explanations and the discursive practices of science are presented. Penney et al. (2003) examined the textual characteristics of junior high science textbooks and found that the textbooks primarily presented facts or conclusions in an expository form. When examining the role of scientific reasoning in the textbooks, they found that on average only 5% of the textbooks involved explanations of phenomena and only 2% included reasons to support other statements. No examples of argumentative text in which ideas were supported by reasons were found.

Studies of elementary science texts have also found that the textbooks pay little attention to explanatory understanding. L.D. Newton et al. (2002) analyzed 76 primary science textbooks and found that the majority of the clauses in the textbooks were statements of fact (median of 85%) and rarely asked students for information or provided reasons for why things are the way they are. Smolkin et al. (2009) conducted a similar analysis of elementary science trade books and identified 67% of the statements as fact and description and the remainder as providing explanatory understanding.

Textbook resources often focus primarily on presentation of facts and descriptions rather than discussion of explanations and the reasons that support them. Argumentative discourse that involves discussion and justification of explanations supported by evidence is an important part of science (P. Newton et al., 1999). When scientific explanations are discussed, students often are presented with the explanations without explicit discussion of the questions that these explanations answer and "the conventional classroom seems to offer science students little, if any, opportunity to design (or even to choose) their own intentional explanations" (Gilbert, Boulter, & Rutherford, 1998, p. 10).

Previous studies have examined how textbooks and associated curricular materials engage students in aspects of scientific reasoning and how they present scientific explanations. Our study extends this work by specifically examining the ways in which textbooks engage students in reasoning about explanations. The specific questions investigated were:

- What opportunities do curricular resources provide for students to reason about scientific explanations?
- What types of explanations do the textbooks emphasize?
- How are the opportunities for students to construct explanations distributed in the various sections of the textbook materials (i.e., text, laboratories, activities, and review questions)?

## FRAMEWORK FOR EXAMINING REASONING ABOUT EXPLANATIONS

We need to begin by defining what we mean by explanations in science. What counts as an explanation and the reasoning involved in formulating explanations have been areas of discussion among philosophers of science, psychologists, and science educators for decades. In general, an explanation is an answer to the question "why?" or "how?" (Nagel, 1961; H. Simon, 2000). However, the views of what constitutes an explanation vary depending upon the purposes for examining this construct (Edgington, 1997).

Philosophers of science are interested in defining explanations in order to determine criteria for what should count as a scientific explanation. Psychologists study explanation in order to better understand the cognitive processes involved in reasoning about explanations. Science educators examine the ways that students and teachers explain scientific phenomena. Teachers use explanations to increase their students' understandings of scientific concepts, whereas students use explanations to make sense of the world around them. In this chapter we are primarily interested in this last category involving students' active sense-making of the world around them. An important part of science learning is providing students opportunities not only to understand scientific explanations, but also to actively engage in making inferences about natural phenomena in order to become independent explainers (Horwood, 1988).

So how do we define what it means to engage students in the process of explaining in science? Some cases are fairly obvious, such as when we ask students to explain why the can collapsed when water was heated in it and then it was placed in a tub of cold water. Cases such as this involve the identification of causal reasons for an event or phenomena. However, what about when we ask students to classify a rock? What if we ask students to classify a rock and provide evidence for their classification? What if we ask students to identify which of a variety of samples are the same substance and explain why? Any of these questions could provide the opportunity for students to engage in reasoning about explanations, although the specific wording, the student's interpretation, or the teacher's guidance may influence whether these questions actually result in explanatory reasoning. One thing that all of these questions have in common is that they require students to make inferences about natural phenomena. In other words, they go beyond merely describing observations or restating concepts that have been learned.

The purpose of the analysis described in this chapter was to better understand the various ways in which curricular materials provide opportunities for students to engage in reasoning about explanations. Therefore, we chose to include in our analysis all tasks that required students to make inferences about natural phenomena. Excluded from this analysis were requests for students to define, describe or explain concepts that had been previously presented in the exact same way in the text. The analysis also does not examine other scientific processes, such as asking questions, designing experiments, making calculations, creating graphs and charts, or making observations. The analytic framework we developed allows for the characterization of these tasks in regards to the various ways in which the tasks provided opportunities for students to reason about explanations.

In developing our analytic framework we drew on previous frameworks of explanation that take a broad perspective in defining the forms that explanations may take (Gilbert et al. 1988; Martin, 1972; Norris, Guilbert, Smith, Hakimelahi, & Phillips, 2005). In these frameworks, explanations may include causal, descriptive, functional, and predictive forms. In describing the nature of explanations, H. Simon (2000) distinguishes between descriptive theories that show how phenomena behave and explanatory theories that provide a causal mechanism for why they behave in that way. Although explanations are sometimes defined strictly as causal accounts, Gilbert et al. (1998) point out that descriptive explanations are often the first steps in scientific inquiry and therefore an important part of the process. We recognize that some people may define explanations more narrowly than we have here, but we believe our broader definition is appropriate in order to characterize how texts engage students in reasoning about explanations.

When conducting a text analysis, we cannot directly determine from the text the various ways that students will provide explanations. The particular reasoning that students use or the levels of specificity that they incorporate into their explanations will be determined by what they see as the purposes of the explanation and the audience for the explanation (Gilbert et al., 1998; Perkins & Grotzer, 2005). We can, however, determine from the text how students are asked to reason about explanations, including the supports that are provided for discussing aspects of evidence and reasoning.

The framework we developed for examining how textbook materials engage students in reasoning about explanations classifies the aspects of an explanatory task at three levels. The first level describes the type of explanatory process the task engages students in, the second level describes the type of explanation that a given question requests, and the third describes the ways in which students are encouraged to support and provide reasoning for their explanations. The three categories are hierarchical in that each task could be coded at all three levels, with each level a sublevel of the previous level. This framework was developed based on existing literature and categories that emerged from the initial analysis. See Figure 4.1. for a summary of the framework. We have chosen to stagger the headings in order to denote the hierarchical nature of the categories.

| | | |
|---|---|---|
| **Type of Explanatory Process** | | |
| Construction of explanations | **Type of Explanation** | |
| Evaluation of explanations | Descriptive explanations | **Support for the Explanation** |
| Application of explanations | Predictive explanations | Discuss evidence |
| | Causal explanations | Identify types of evidence |
| | Functional explanations | Evaluate evidence |
| | Models | Explain reasoning |

*Figure 4.1. Summary of the framework for examining explanatory tasks in textbooks.*

### *Type of Explanatory Process*

This category acknowledges that although a large part of science involves the generation of scientific explanations, science also involves the evaluation and application of scientific explanations (Ohlsson, 1992; Thagard, 2006). Instances in which students were asked to construct explanations included being asked to generate descriptive or explanatory claims. Evaluating explanations consisted of situations in which students were provided with a claim or multiple claims and asked to determine how well the explanation or explanations fit the phenomena. Also included in this category were situations in which students were asked to evaluate their own hypotheses after conducting investigations. Applying explanations refers to what Ohlsson (1992) calls theory articulation or “the activity of applying a theory to a particular situation, to decide how, exactly, the theory should be mapped onto that situation, and to derive what the theory implies or says about that situation” (p. 182). For example in a review question students were asked, “If the ‘shrinking apple’ theory for mountain formation were correct, explain where you think mountains would be found on Earth’s crust” (Booth et al., 2001a, p. 394). In our analysis we included instances where students were asked to apply scientific claims to particular situations, but not instances where students were asked to apply scientific ideas to design technological products.

The reasoning required to generate and choose between theories differs from that required to apply theories to particular phenomena. When generating and evaluating theories students must identify patterns in evidence, distinguish between evidence and theory, and evaluate evidence in light of possible theories. When applying theories to particular situations the theory is known and the evidence is constrained to a specific context. In the application case, the reasoning requires an articulation of how the evidence relates to the theory and which aspects of the theory can explain the evidence. Since the theory is provided, the reasoning focuses primarily on identifying the relationships between the theory and the evidence. This involves primarily deductive reasoning rather than inductive reasoning that is characteristic of generating and evaluating explanations.

### *Type of Explanation*

Explanations were identified as belonging to one of five categories: (a) descriptive, (b) predictive, (c) causal, (d) functional, and (e) models (Gilbert et al., 1998; Martin, 1972).

Examples of requests for descriptive explanations included: describe characteristics, identify relationships, identify patterns, and classify. When coding explanations in this category it was necessary to make a distinction between tasks that required students to make only observations and tasks that required students also to make generalizations based on observations. Tasks that were coded *describe characteristics* involved situations in which students were asked to summarize observations, such as, “Write a summary paragraph describing what you learned about the composition of soil in this activity” (Booth et al., 2001a, p. 389). In this case students were asked to bring together multiple observations to make a generalization about the characteristics of something. Tasks were coded *identify patterns* when students were asked to generalize relationships between a number of observations or data points and *identify relationships* when students were asked to generalize the relationship between two sets of observations.

Classification is included in the category of descriptive explanations, although the construction of explanations of this type may include both descriptive and explanatory elements (Rehder, 2003; Rehder & Kim, 2009; H. Simon, 2000). Classification involves knowledge of specific features and the causal mechanisms that link those features (Rehder, 2003). The determination of which features are relevant for category membership may be influenced by knowledge of the causal relationships between observable features (Ahn, Kim, Lassaline, & Dennis, 2000) or by causal relationships linking observable features to unobservable properties or structures (Rehder, 2003).

Predictive explanations answer the question of how a phenomenon might behave under particular conditions (Gilbert et al., 1998). Predictions may involve deductive inferences from hypotheses and generalizations, or inductive inferences based on extrapolations from patterns of past events (Gibbs & Lawson, 1992). Included in this category were tasks in which students were asked to make predictions about what might happen in the future and tasks involving retrodiction in which inferences are made about events that have happened in the past. Retrodiction is common in fields such as geology and paleontology (Govier, 2009).

Causal explanations included tasks that explicitly asked students to identify causes or effects and tasks that required causal reasoning in order to prevent effects or determine rates of change. Although students are not directly identifying the causes or effects of an event when stating how they would prevent an event from happening, by identifying the ways in which a certain outcome might be prevented students are explaining a certain form of causal relationship (Hoerl, 2009).

Determining rates of change was also included in our framework as a form of causal explanation. In order to determine rates of change, students must examine the phenomena of interest, determine the underlying causal mechanisms responsible for the change, and then infer how the causal mechanism may be influencing the change. For example, when shown a picture of a mountain with slanted rock layers or a fossilized insect in amber and asked "Do you think this change happened slowly or quickly?" (Booth et al., 2001a, p. 350), students must determine the underlying causes for the change in order to determine if the change occurred quickly or slowly.

The development of hypotheses has also been included under the category of causal explanations, because in theory these should involve the construction of possible causal explanations for an observed phenomenon (Gibbs & Lawson, 1992). However, when coding the text for situations in which students were asked to construct or evaluate hypotheses we found that the texts' presentation of hypotheses was often problematic. What were identified as hypotheses in the texts were often predictions or in some cases not clearly identifiable as predictions or causal explanations. For example, students were asked in one lab, "How can you identify a mineral by its properties?" Students were then asked to "Develop a hypothesis based on the question above" (Booth et al., 2001a, p. 374). It is unclear in this case what sort of hypothesis the text is intending the students to develop. Student responses could describe ways that they will be able to use a mineral identification chart, which is primarily a procedural description. Alternatively they could describe the types of properties that would be useful to describe minerals, which gets at aspects of classification and the nature of the evidence used for classifying minerals. In either case, the hypothesis does not involve a discussion of causal explanations or even predictions of phenomena. We decided to include all instances where the text noted that a hypothesis was being sought. If we were able to determine the nature of the hypothesis requested, a prediction or causal explanation, then we also coded it as that type of explanation.

Functional explanations included tasks in which students were asked to make inferences about an organism's or object's function based on its structure or to make inferences about its structure based on its parts. For example, when provided with pictures of fossils, students were asked to make inferences about how the animal moved, where it lived, or how it ate (Booth et al., 2001a, p. 416). Martin (1972) and Gilbert et al. (1998) have pointed out the problematic nature of functional explanations and question whether they actually provide an explanation. However, as Martin (1972) noted, functional explanations play an important role in biology, especially in initial stages of inquiry and therefore we have included them in our framework.

Our framework also identifies tasks in which students are asked to create, evaluate or apply models. A model is a verbal, mathematical, or visual representation of a scientific structure or process (Gilbert et al., 1998; Ingham & Gilbert, 1991). For example, students were asked to draw a model of the contents of a mystery container (Booth et al., 2001a, p. 353), evaluate models of the earth's interior (Booth et al., 2001a, p. 356), and create a mathematical model to represent the relationships in a ray diagram (Edwards et al., 2001, p. 191). The construction of models involves "integrating pieces of information about the structure, function/behavior, and causal mechanism of the phenomenon, mapping from analogous systems or through induction" (Gobert & Buckley, 2000, p. 892).

### *Support for the Explanation*

This level focuses on the structural components of explanations that the text prompts students to include. Toulmin (2003) describes the structure of everyday arguments as including data, claims, warrants, backing, qualifiers, and rebuttals. The Toulmin framework has been used in science education to examine the nature of students' construction of explanations and arguments (Erduran, S. Simon, & Osborne, 2004). To examine the curricular supports for engaging in reasoning about explanations we drew on a previous framework, which breaks down explanation into three structural components based on Toulmin. These three components are (a) the claim or answer to the question, (b) the evidence used to support the claim, and (c) reasoning that provides evidentiary or explanatory support for the claim (McNeill, Lizotte, Krajcik, & Marx, 2006). These three components are used to determine how the text prompts students to support their explanations with evidence and reasoning.

We identified four different ways in which students were asked to reason about evidence: (a) discuss specific evidence for claims, (b) identify types of evidence to construct claims, (c) evaluate limitations of evidence, and (d) evaluate usefulness of evidence. In some cases students were asked to discuss specific evidence for claims and in other cases they were asked to identify types of evidence that could be used to construct claims. An example in which students were asked to identify types of evidence rather than describe specific evidence is seen in the following task: "You have been asked to join a scientific expedition to investigate a remote mountain region in the Antarctic. Your team wants to discover how these mountains formed. Describe the evidence you will look for" (Booth et al., 2001a, p. 408). In these cases, the instruction was hypothetical. There was no specific evidence that the students were reasoning about. Rather, the task required them to think about the nature of the evidence that would be appropriate to construct explanations of this type. Students were also asked to evaluate the usefulness or limitations of evidence, such as, "What physical property (or properties) did you find the most useful in classifying rocks?" (Booth et al., 2001a, p. 383) and "What uncertainties do scientists face when they investigate fossil evidence? Why do they need to investigate a variety of fossil evidence before making conclusions?" (Gue et al., 2001, p. 420). Having students evaluate the usefulness and limitations of evidence supports students in critically analyzing the relationships between evidence and claims and in better understanding the complexities of this relationship.

Our framework also identifies places in the text where students are asked to further explain reasoning for claims or conclusions. With this categorization we were interested in identifying places where students were prompted to explain connections between claims, evidence, and concepts. Coding statements of this type could not simply be done by looking for terms and explanations containing words such as 'explain', 'why', or 'why not', because these sometimes could be asking students to state claims, evidence, or reasoning. When coding these statements we looked at the statement in context and coded it as explain reasoning only when the text explicitly asked for some sort of claim or a specific claim was provided and then asked for further reasoning to support that claim. For example, "Which property or properties did you find the most useful for identifying minerals? Why?" (Booth et al., 2001a, p. 375) "Summarize the evidence you found. Does it support your prediction? Explain why or why not?" (Gue et al., 2001, p. 370) and "Identify each fossil type shown in the photographs on pages 418 and 419. Explain how you decided" (Gue et al., 2001, p. 422).

*Summary*

The framework we have described characterizes how curricular materials engage students in reasoning about explanations. Text analyses using this framework can determine the content of the explanations and how students are prompted to provide explanatory and evidentiary support for their claims. This information points to opportunities that students are provided for reasoning about explanations and provides insight into the types of reasoning that students might use when formulating explanations.

## METHOD

### *Curricular Materials Selection*

Curricular materials from two junior high science programs were chosen for this analysis: *ScienceFocus 7* (Gue et al., 2001), *ScienceFocus 8* (Edwards et al., 2001), *Science in Action 7* (Booth et al., 2001a) and *Science in Action 8* (Booth et al., 2001b). These included both the textbook and associated teacher resources. The textbooks in both programs included five instructional units that contain content aligned with the Alberta Program of Studies for Science. Each unit of the textbooks included text, figures, activities, investigations, and review questions. Alongside the text of the *ScienceFocus* textbooks were small sections that provided interesting facts, science journal activities, internet research activities, vocabulary development activities, technology, mathematics, and career connections. The *Science in Action* textbooks included small sections with information on science facts, internet/library research activities, questions focused on aspects of the nature of science, and mathematics connections. The associated teacher resources included additional laboratories, reinforcement worksheets, and sample quizzes and unit tests.

In the Alberta Program of Studies, science units are designed to include a focus on the Nature of Science, Science and Technology, and on the Social and Environmental Contexts of Science and Technology. Although any of these units could engage students in reasoning about explanations, it was determined that the Nature of Science units would most likely contain these sorts of activities. The Nature of Science units emphasize the role of observation, evidence, interpreting, predicting, and explaining in science as evident in the statement regarding the Nature of Science in the Alberta Program of Studies for Science, grades 7-8-9:

> Science provides an ordered way of learning about the nature of things, based on observation and evidence. Through science, we explore our environment, gather knowledge and develop ideas that help us interpret and explain what we see. Scientific activity provides a conceptual and theoretical base that is used in predicting, interpreting and explaining natural and technological phenomena. Science is driven by a combination of specific knowledge, theory and experimentation. Science-based ideas are continually being tested, modified and improved as new knowledge and explanations supersede existing knowledge and explanations. (Alberta Learning, 2003, p. 4)

Due to this emphasis, we decided to focus our analysis on these units, which resulted in the selection of one unit from each grade level: *Planet Earth* for grade 7 and *Light and Optical Systems* for grade 8.

### *Text Analysis*

In order to examine all components of the textbook and associated curricular materials, it was necessary to choose a unit of analysis that could be applied to text, figures, activities, investigations, and review sections. Our unit of analysis was therefore defined as an *explanatory task*. An explanatory task was defined as any exercise that involved the generation, evaluation, or application of descriptive or explanatory claims, or tasks that engaged students in reasoning about the evidence for claims. Explanatory tasks could consist of: (a) a section of text or figure that asks students questions, (b) an activity, (c) a laboratory, or (d) a review question.

Tasks in which the answers to the questions were directly provided in the text were not included in this analysis. At the start of the chapter the text sometimes asked rhetorical questions that were then immediately answered or the text pointed out when in the chapter the question would be answered. Review questions sometimes appeared to require students to construct claims based on what they had learned, but a search of the text showed that the answer was provided and only required students to find that answer. Neither type of task was included.

The texts were coded by two raters working independently. Ratings were then compared and, in cases where there were differences in coding, each case was discussed until agreement was reached.

## FINDINGS AND DISCUSSION

In this section we first examine how the texts engaged students in constructing, evaluating, or applying explanations and how these opportunities for reasoning about explanations were distributed among the text sections. We then examine the types of explanations that the texts engaged students in constructing. Lastly, we discuss the supports that the texts included for students to provide evidence and reasoning for explanations.

### *Type of Explanatory Process*

In both the *Planet Earth* and the *Light and Optical Systems* units students were more frequently asked to construct explanations than to apply or evaluate. This finding is not surprising, because constructing explanations is an important part of science and science learning. However, there was limited inclusion of opportunities for evaluating and applying claims showing that the texts are missing opportunities for the students to engage in these important aspects of reasoning about explanations. As has been argued by others, applying and evaluating claims are important components of science (Ohlsson, 1992; Thagard, 2006). Evaluating and applying claims also engages students in critically analyzing explanations in ways that may or may not occur when explanations are constructed.

Both textbooks and both units were found to provide students the possibility to engage in reasoning about explanations. The textbooks integrated opportunities for reasoning about explanations in the review questions and the text sections, as well as in the laboratories and mini-activities. Although we cannot directly compare the number of instances of explanatory tasks in laboratories to text sections we can compare the way the explanatory tasks were distributed among different sections. In the *Light and Optical Systems* unit, the explanatory tasks were distributed similarly among section types in both *ScienceFocus* and *Science in Action*. However, in the *Planet Earth* unit, *ScienceFocus* was more likely to engage students in constructing claims during laboratory activities than in any other areas of the text, whereas *Science in Action* was more likely to incorporate reasoning about explanations throughout the textbook and associated curricular materials. In addition, the evaluation of claims in the *ScienceFocus Planet Earth* unit occurred only in the labs, whereas *Science in Action* included opportunities to evaluate claims in the mini-activities and review questions as well.

The integration of reasoning about explanations throughout the text is more likely to encourage teachers and students to see this as an integral part of science and science learning, rather than something to be done only during labs. However, it should be noted that the use of explanatory tasks is dependent on specific teacher approaches. For example, students' engagement with the explanatory tasks embedded in the text will depend upon whether the reading is assigned for independent work or is used interactively with the students. The opportunities that were embedded in the text allow students to reason about explanations as they are reading about new concepts and ideas. This supports their meaning making of the ideas and allows students to consider how the ideas apply to other situations and their own lives. However, if textbook reading is assigned as independent work, then students may not take advantage of these opportunities. Many of the explanatory tasks that are embedded in the text were included in the figures and supplementary information set in the margins that accompanied the text. When engaged in independent reading, students often ignore the figures and supplementary material that is separated from the main text (Weidenmann, 1989).

### *Types of Explanations*

In both the *Planet Earth* and *Light and Optical Systems* units students were engaged in constructing a variety of types of claims, including descriptive, predictive, causal, functional, and model-based claims. The *Planet Earth* unit included a few types of claims that were not present in the *Light and Optical Systems* unit, such as retrodiction, preventing effects, determining rates of change, and inferring structure from parts. These types of claims are specific to the geological content in the *Planet Earth* unit. Even though the current analysis examined only units from two different content areas, this analysis does show that there are likely to be differences in the types of claims and in the nature of the reasoning required to construct different types of claims. For example, as described earlier, determining rates of change requires examining the situation, considering causal factors influencing the changes that are occurring, and then inferring how those causal factors may be influencing rates of change. This combination of descriptive and causal reasoning differs from explanatory tasks that ask students only to directly identify causes or effects, which were more common in the *Light and Optical Systems* unit.

When examining the types of claims that students were asked to evaluate we found that the texts engaged students in evaluating theories and models, specific claims stated by the text or other students, and their own hypotheses and predictions. However, the two texts differed in the emphasis placed on the types of claims that were evaluated. *ScienceFocus* was more likely to engage students in evaluating their own predictions and hypotheses than *Science in Action*. *Science in Action* was more likely to engage students in evaluating a variety of types of claims, including their own hypotheses, scientific theories, and models.

### *Support for the Explanation*

Students were asked to construct claims much more often than they were asked to discuss the nature of evidence or explain their reasoning. Students were often asked to construct, evaluate, or apply claims without specific requests to support those claims with evidence or reasoning. It is possible that students would include aspects of evidence and reasoning in their explanations, but our analysis shows that the textbook materials rarely explicitly ask for these important components of explanations. Teachers could incorporate these supports into classroom discussion and supplementary materials, but without the detailed supports being present in the text, this puts more responsibility on the teacher to provide this support.

Even though the explicit requests for students to discuss aspects of evidence and reasoning were limited in the text materials, overall the texts asked students in a variety of ways to reason about evidence. Students were most commonly asked to discuss evidence for claims, and in a few instances students were asked to evaluate the value and limitations of evidence, and to identify types of evidence that would be needed to support claims.

Comparison of the texts shows differences in the level to which they included these opportunities. The *ScienceFocus* text was the only one that engaged students in explicitly discussing the limitations of evidence. This is an important part of understanding the relationship between evidence and explanation and is interesting that this is entirely missing from one of the texts.

The *Planet Earth* unit asked students in a wider variety of ways to reason about evidence than the *Light and Optical Systems* unit. This was evident in regards to supports for providing evidence and reasoning. In the *Light and Optical Systems* unit there was only one instance in which students were asked to identify types of evidence, one instance where students were asked to evaluate the usefulness of evidence, and nowhere in the unit in either text were students asked to evaluate limitations of evidence. The difference between these two units might suggest to students that the nature of the explanations in the *Light and Optical Systems* unit are more straightforward and less consideration is needed of the evidence that supports the ideas in this unit. These differences between content areas need to be examined in more depth in future studies. Engaging students in examining the nature of evidence and supporting their explanations with reasoning is important in order to support students in better understanding the relationships between evidence and explanations.

## CONCLUSIONS AND IMPLICATIONS

Our primary goals were to identify the nature of the opportunities and supports for reasoning about explanations in current science textbook materials. In order to do this we developed a framework for examining the various ways that texts might engage students in reasoning about explanations and the supports for students to provide evidence and reasoning for explanations.

The results of the analysis of two units from two different publishers suggest that the texts provide multiple opportunities for students to engage in the construction of explanations, and more limited opportunities for students to evaluate and apply explanations. There is a need for increased opportunities for students to engage in the application and evaluation of scientific explanations. Through such opportunities, students will more likely develop the skills needed in negotiating competing scientific claims, as well as in discerning the connections between and among claims, evidence, and reasoning.

Our analysis also found that the texts provide limited prompts for students to support their explanations with evidence and reasoning. Previous studies have found that students often use inadequate evidence to support their claims (Jiménez-Aleixandre, Rodríguez, & Duschl, 2000; Sandoval, 2003; Watson, Swain, & McRobbie, 2004) and that providing explicit supports can improve the quality of students' explanations (Sandoval & Millwood, 2005). Textbook materials are an important place to provide these supports.

By becoming more aware of the opportunities that already exist in the textbook materials for reasoning about explanations, teachers could further capitalize on these affordances. Teachers could build on the current curriculum by utilizing the prompts that already exist in the textbook materials for constructing explanations and, where aspects of reasoning about explanations are omitted or inadequate, provide additional supports to encourage students to further discuss the evidence and reasoning for their explanations.

Our framework for examining the nature of explanations could also be used by curriculum designers to examine the opportunities for reasoning about explanations within curriculum materials and to diversify these reasoning experiences.

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