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Reasoning about the Seasons: Middle School Students' Use of Evidence in Explanations

Abstract: This study examines the ways in which middle school students approach problems which require scientific reasoning about seasonal change. Pre/post instructional assessments with students from five classrooms (N=38) showed significant improvement in understanding of the seasons though less than a third could be classified as having the scientific mental model. Students' limited use of observable evidence in reasoning both pre and post indicates the need for further instruction on scientific reasoning in this domain.

Introduction and Theoretical Framework

A significant body of research has examined and described the wide range of alternative ideas in astronomy (e.g. Bailey & Slater, 2004). Far less research investigated instructional strategies that can improve students' understanding of these topics (Bailey & Slater, 2004) and fewer still have investigated scientific reasoning in the domain of astronomy suggesting that this is an under studied area of astronomy education research. Recent synthesis documents in science education, such as *Taking Science to School* (NRC, 2007), promote both the importance of understanding the challenges in changing children's conceptual frameworks but also in the importance of providing opportunities to develop further abilities in scientific reasoning. Further, the fact that "scientific reasoning is intimately intertwined with conceptual knowledge" of natural phenomena imply that research must be designed to investigate this interplay within different disciplines (NRC, 2007, p. 129). This article examines students' use of evidence in explanations about the reasons for the seasons to assess how their growth in conceptual knowledge influences their reasoning strategies.

Literature Review and Theoretical Framework

One of the challenges facing progress in improving scientific literacy is that school science frequently tends towards disconnected facts rather than a designed focus on conceptual goals that build over time (Corcoran, Mosher & Rogat, 2009). We locate this study of children learning about the seasons in a learning progression framework because learning progression-based research provides a way to develop long-term empirically based organizations of concepts towards big ideas in science. Learning progressions (LP) are hypothetical descriptions of how students understanding of big ideas in science become more sophisticated through targeted instruction across time (e.g. NRC, 2007). Big ideas hold broad explanatory power in the domain, make connections across isolated concepts, and are developed over time as learners understanding them in increasingly sophisticated ways (e.g. NRC, 2007). As students will not reach scientific understanding of big ideas without targeted instruction, a major goal of LP research is to identify instructional practices that will move students towards more sophisticated levels of understanding. One of the central concepts of astronomy experienced by humans is the changing of the seasons; yet extensive research has shown the prevalence of alternative ideas about this conceptual area (e.g. Sharp, 1996) and the resistance learners have towards developing full understanding (e.g. Schneps & Sadler, 1988). This, in itself is not a big idea but rather the more generalized concept of *celestial motion* allows us to unify this concept with other related concepts in astronomy (Author, 2009).

Songer, Kelsey, and Gotwals (2009) have laid out the argument for integrating content and inquiry reasoning into learning progressions, rather than focusing on content alone. Their learning progression is developed around dual strands: the big ideas of *biodiversity* and *evidence-based explanations*. The results of this study will allow us to take a critical first step towards developing an integrated learning progression hypothesis and plan for further instruction to test our theories in this area. This study is guided by the following research questions: 1. Do students provide explanations that make connections to evidence when reasoning about celestial motion and the season? 2. How does increased understanding of the content impact students' use of observable evidence when reasoning about the seasons?

Research Design

Participants in this study were sampled from students in five of the 2nd Author's 8th grade science classes (N=38). The curriculum was based on activities from The Real Reasons for Seasons (Gould, Willard, & Pompea, 2000), Project Star (Harvard Observatory, 2001), and teacher-created materials. The pre/post assessment consisted of five multiple-choice questions and five open responses questions (Pyke, private communication). Student responses to both the multiple-choice items and the open-ended prompts were aligned to levels on a scoring guide to examine change in understanding. The open response questions allowed us to code for students' use evidence and scientific reasoning in discussing problems related to the seasons. Initial open-coding led us to patterns in the data that were explored more rigorously by defining a coding scheme.

Results

The results of a paired samples t-test was performed indicate that there was significant improvement from the pretest to the posttest for the combined global and local conditions ($t= -7.211$; $p=0.00$). However, only a quarter of the students were able to provide scientifically accurate responses for questions about the seasons after 10 days of activities and investigations. We present two examples of our analysis of students' reasoning opportunities. First, students were asked to first draw the location of a shadow cast by a pole in the afternoon (the image showed the sun's location and the pole's shadow for the morning) and then to explain this motion. Prior to instruction, most students used the earth's motion (both scientific and non-scientific motions) to explain why the shadow appeared to move though some used the sun's motion (actual or apparent) to explain the shadow's motion. However after instruction, were far less likely to make a clear connection between the observation (the shadow's motion) and their explanation. Prior to instruction, only one student's reasoning did not match the evidence presented. After instruction, at least 10 students gave a reason that did not logically correspond to the evidence they presented. Second, we examined whether or not students could use changes in the observable pattern of sunlight either in Scenario A (temperature changes with latitude in water along Atlantic Coast) or in Scenario B (temperature changes in water between Summer and Winter at a given location) when specifically prompted to use what they know about light from the sun. Prior to instruction, less than half (N=13) gave answers that used the concept of the sun's light to explain Scenario A, and fewer of these students (N=7) provided reasoning to explain the change in sunlight. These numbers increased after instruction, where a slight majority (N=20) used changes in the sun's light in their explanation though only nine of these students attempted to provide reasoning to explain this change. A similar shift in the fraction of students using the sun's light (Pre: N=10; Post: N=19) and providing reasoning (Pre: N=1; Post: N=10) was seen for Scenario B. Many of the remaining students focused on either distance from the equator, a generalized sense that the location is "facing" the sun more or less, and the use of the earth's tilt without connection to changes in sunlight.

Discussion and Implications

Learning to explain the seasons is a highly complex topic involving the ability to explain observable evidence relating to patterns of sunlight with the combined rotational and orbital motion of the earth on its tilted axis. While these middle school students showed improvement in their understanding, the magnitude of this improvement was limited. Further, student responses indicate that additional guidance in using observational evidence will be necessary to advance their ability to reason scientifically about the seasons using observational evidence. Students' attempts to reason about the earth's rotation suggests that because many students did not have a strong understanding of this concepts, instruction on the tilt model may have "distracted" students from applying appropriate reasoning strategies to a simple problem of the shadow cast by the sun over a day. In developing an integrated content and inquiry learning progression in this area we will need to examine changes in students' use of evidence and ability to connect their explanatory models to the observations they can make of the world. We argue that providing extensive experience learning and applying the observable evidence for seasonal change will provide students with the richest opportunity to construct the full understanding of the seasons. Without the observational understanding, the use of the "tilt model" is meaningless.

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