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

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Abstract: This study examines the ways in which middle school students (N=39) approach problems which require scientific reasoning about seasonal change and how this relates to their overall improvement across the domain. Students' limited use of observable evidence in reasoning about observational astronomy concepts indicates the need for further instruction on scientific reasoning in this domain.

Introduction

Recent research syntheses, such as *Taking Science to School* (NRC, 2007), promote the importance of both understanding the challenges in changing children's conceptual frameworks but also in the importance of providing opportunities to further develop their abilities in scientific reasoning. Given 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.

Theoretical Framework

We locate this study of children learning about the seasons in a learning progression framework. 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). 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). The seasons, in itself is not a big idea but rather a manifestation of the more generalized concept of *celestial motion* that unifies this with other related concepts in astronomy (Plummer & Krajcik, 2010). We do not present a full learning progression, across multiple grade-bands in this study; rather we focus on aspect of the progression in more detail and the ways in which these connect to earlier conceptual development on the progression (Plummer & Slagle, 2009). Songer et al. (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 preliminary research on children reasoning about the seasons 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 celestial motion. We are guided by following 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 were students in five of Lori Agan's 8th grade science classes (N=39). The 10-day curriculum was based on published curricula and teacher-created materials. The pre/post assessment consisted of six multiple-choice questions and seven open-responses questions. The open response questions were assigned codes for scoring. Inter-rater reliability for the pre and post open response questions for 15 students (38% of the set) was 94% (by scores) and 89% (by individual codes). Student responses to both the multiple-choice items and the open-ended prompts were aligned to levels on a 4-level scoring guide to examine change in understanding.

Results

The results of a paired samples t-test indicates that there was significant improvement from the pretest to the posttest ($t= -7.458$; $p<0.001$). However, only eight students (21%; compared to 1 student prior to instruction) were able to provide scientifically accurate responses (which did not also include alternative ideas) on at least 6 out of 7 seasons-concept questions. We present three cases in our analysis of students' reasoning about the seasons, from different levels of the learning progression. First, we analyzed student reasoning on a lower level of the learning progression: use of the earth's rotation. Students were given an image showing the sun's location and a pole casting its shadow in the morning; they were asked to draw the location of a shadow cast by a pole in the afternoon and then to explain this apparent motion. Table 1 shows the change in use of the earth's rotation and our examination of students' reasoning. After instruction, students were significantly less likely to make a clear connection between observation and explanation (students did not provide evidence or gave a reason that did not logically correspond to the evidence they presented). Second, Table 1 shows the results of Scenario A (temperature changes with latitude in water along Atlantic Coast) and Scenario B (temperature changes in water between summer and winter at a set location), where students were specifically prompted to reason with what they know about *light from the sun*. This type of reasoning is an important step in the progression towards scientific sophistication on the seasons (Plummer & Agan, 2010). Note that this analysis is not looking at scientifically accurate uses of light and explanations but rather how they attempt to reason in these situations (change in number of accurate responses is also reported in Table 1). Significant change was only found for understanding in Scenario A and increased use of explanation for Scenario B.

Table 1: Three cases of students connecting explanations with evidence in the seasons (N=39)

	Pre	Post
Earth's rotation - Accurate use to explain observations	14 (36%)	22 (56%)
Earth's rotation - Explanation logically corresponds to evidence***	39 (100%)	27 (69%)
Scenario A – Use of light	19 (49%)	21 (54%)
Scenario A – Explanation for change in light	12 (31%)	16 (41%)
Scenario A – Scientific response to question*	3 (8%)	11 (28%)
Scenario B - Use of light	13 (33%)	19 (49%)
Scenario B - Explanation for change in light*	3 (8%)	11 (28%)
Scenario B - Scientific response to question	9 (23%)	13 (33%)

X^2 test - $p<0.05$: *; $p<0.001$: ***

Discussion and Implications

Learning to explain the seasons involves the ability to explain observable evidence relating to patterns of change in sunlight with rotational and orbital motion of the earth on its tilted axis. Student responses indicate that additional guidance in using observational evidence will be necessary to advance their ability to reason scientifically about the seasons. First, students' attempts to reason about the earth's rotation suggests that because many students did not have a strong understanding of this concept initially, instruction on the tilt model may have "distracted" students from applying appropriate reasoning strategies. Students' difficulty in this lower level of sophistication on the learning progression may have inhibited progress in the more sophisticated levels (Plummer & Agan, 2010). Second, students showed some improvement in scientific knowledge of how changes in sunlight across the seasons and across locations on the earth affect seasonal temperature changes. But many students did not attempt to use sunlight to reason about changes in temperature or to attempt to explain changes in sunlight. In our poster, we will consider how instruction in this intervention may have supported some but not all students in moving forward in their reasoning about the seasons and the implications for future curriculum interventions and research. Our results suggest that successful instruction along the celestial motion progression will first support students in use of the earth's rotation on daily apparent motion; then provide students with experience in applying the observable seasonal change to temperature pattern; and finally support students in constructing explanations that use the tilt model in a way that uses reasoning between frames of reference. Without the observational knowledge, the use of the "tilt model" is meaningless.

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