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Preservice Teachers' First Experiences Teaching Astronomy: Challenges in Designing and Implementing Inquiry-Based Astronomy Instruction for Elementary Students in After School Programs

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Abstract. This study examined preservice teachers' pedagogical content knowledge (PCK) in designing astronomy investigations for children. Fifteen pairs of preservice teachers taught groups of children in after school programs once a week for five weeks; their assignment was to guide the children in a multi-day inquiry investigation about astronomy. Pre- and post-program content assessments and five lesson plans from each pair were analyzed using a mixed-methods approach to understand the successes and challenges in developing PCK by new teachers in this domain. Findings suggest that while most preservice teachers were able to implement inquiry investigations in elementary astronomy topics, many also struggled to successfully connect a scientific question to an explanation based on evidence. A correlation between the teachers' content knowledge and the sophistication of their investigation plan was found.

1. Introduction

State and national standards suggest that students in elementary school should be learning astronomy while also engaging in the practices of science (e.g., National Research Council 2011). Research is needed to uncover the ways elementary teachers design instruction that applies scientific inquiry to the domain of astronomy as well as methods of supporting their pedagogical knowledge through professional development and curricula. A pedagogical content knowledge (PCK) framework was used to interpret dimensions of preservice teachers' development during an elementary science methods course. PCK describes teachers' understanding of how to design the learning environment to support children's development of specific content and practices. This paper focuses primarily on their knowledge of instructional strategies and representations for teaching science (Magnusson, Krajcik, & Borko, 1999). Though some research on teachers' PCK in astronomy exists (Henze et al. 2008; Plummer & Zahm 2010), questions remain regarding specific features of elementary teachers' PCK in astronomy.

Elementary teachers, who are often non-science majors, have particular challenges in developing PCK in astronomy. First, new teachers may have limited understanding of how to tailor the learning environment to their students (e.g., Grossman 1991). Second, many teachers do not have scientific understanding of elementary astronomy topics (e.g., Plummer, Zahm, & Rice 2010). Third, research has shown that teachers, especially elementary teachers who are prepared as generalists, often do not under-

stand scientific practices or the nature of science (e.g., Lederman et al. 2002). These challenges led to the following research questions:

1. To what extent are preservice teachers able to design inquiry-based, extended investigations in elementary astronomy?
2. How did their knowledge of elementary astronomy impact the sophistication of the investigations developed?

2. Methodology

Participants were preservice teachers in a 15-week elementary science methods course taught by the author (and co-taught by an instructor not involved in the study) at a small, private suburban university. All preservice teachers in each of three sections participated in the study (30 teachers total). Participants were primarily female (29) and Caucasian (23). Two sections were designated for undergraduates (18) while the third was for a post-baccalaureate certification program (12); however, the instruction and assignments for all three courses were identical. While most participants had no prior teaching experience, seven had prior experience teaching pre-K children, one had taught at the high school level, and one at the elementary level. Only three participants had studied astronomy in high school or beyond, and many could not recall ever having studied astronomy.

The following experiences define the first five weeks of the course: in-class guided inquiry instruction on astronomy concepts, discussion of reform-based readings on science in the classroom (e.g., National Research Council 2000, 2007), analysis of a commercially available curriculum (Full Option Science System 2007), and feedback from their professors as they developed lesson plans for fieldwork. During the second five weeks of the class, pairs of teachers designed and implemented lessons once a week in an afterschool program. Each pair was assigned to teach a group of four to ten children from grades K–6 across the five weeks of the program; children were grouped by grade level. The preservice teachers' assignment was to design and implement an extended inquiry investigation on elementary-level astronomy concepts.

A coding scheme was developed to analyze the lesson plans by identifying 1) specific inquiry practices, and 2) connections between practices and across lessons. The science practices described in the Inquiry in the National Science Education Standards (INSES; National Research Council 2000) were used in determining the level of sophistication in the extended inquiry presented by the teachers. Each lesson was coded individually as well as across lessons from each pair of students.

The second research question was addressed quantitatively. The codes developed to describe the use of inquiry practices were organized into categories for different types of investigations (looking across lesson-sets), as shown in Table 1. This was used to create an ordinal, ranked scale for the sophistication level of each lesson-set. The Spearman's ρ (or r_s) correlation was computed between the investigation scale and both pre- and post-content assessment scores using SPSS.

3. Findings

Research question 1: Each pair's five lesson plans were categorized using the criteria in Table 1; each pair of preservice teachers were assigned the level of the most sophisticated set of lessons created. Table 2 shows the frequency of pairs at each level as

Table 1. Levels of sophistication for investigations using *INSES* criteria

Level 1	Investigation question must lead to examining data for evidence towards answering the question. An explanation must be constructed in response to the investigation question and must explicitly use evidence as support.
Level 2	Investigation uses a question that leads to interrogating data for evidence but leave the connection between evidence and explanation *implied*.
Level 3	Lessons allow children to engage with data in response to a question but do not attempt to construct an explanation in response to the question.
Level 4	Uses scientific practices but does not meet above criteria.

well as the number of lessons that the pair's investigation extended. Level 1 is most sophisticated while Level 4 included zero lessons classified as an investigation.

Table 2. Frequency (number of teacher pairs) and length (number of lesson) for each level of investigation

Group	Level 1	Level 2	Level 3	Level 4
Undergraduate	4 [2, 2, 2.5, 4.5 lessons]	1 [1 lesson]	1 [1 lesson]	3
Non-traditional	3 [5, 5, 5 lessons]	2 [3, 4 lessons]	0	1

Seven pairs (47%) developed extended investigations extending from two to five lessons. Investigations were typified by the following structure: the teachers posed an investigation question that concerns a pattern of observations (such as the Sun's path or the phases of the Moon). Observations were made and recorded to determine this pattern. A preliminary explanation was offered that used evidence to construct a representation of the Earth-based observable pattern. The investigation then continued as the teacher engaged children to think about why the observational pattern exists through a psychomotor and/or kinesthetic modeling activity. An explanation was then constructed that drew upon the observational evidence to design or evaluate the space-based model of motion or observing orientation.

Some pairs were able to designate a *scientific question* that lead to collecting data (4 pairs; 27%) but fell short when it came to *connecting evidence to an explanation*. Teachers followed data collection and analysis with a broad summarizing question but no support or explicit guidance for constructing an evidence-based explanation. These were categorized as an *implied* use of evidence because of the temporal proximity of this summarizing event to the data collection phase. Other teachers did not make explicit connections between the initial observational pattern and the modeling activity; thus, the explanation from a space-based perspective lacked a clear evidence base. Finally, four pairs (27%) did not create extended inquiry investigations. These pairs either lacked a clear investigation question, the teachers answered the investigation question before collecting and analyzing data, or investigation questions lead to rote activities, such as completing worksheets.

Research question 2: Initially, the preservice teachers had a low level of knowledge of elementary astronomy, with a mean score of 8.8 (standard deviation = 2.9) out

of 24 on the content assessment. The mean score on the post-test was 13.8 (standard deviation = 3.2), a statistically significant improvement ($t = 9.437$, $p < 0.001$). Though no correlation was found with the pre-test scores ($r_s = 0.332$, $p > 0.05$), a significant correlation between investigation-scale level and the post-test score was found ($r_s = 0.552$, $p < 0.01$). Teachers who developed an overall greater understanding of astronomy during the course showed greater sophistication in the investigation level they designed.

4. Conclusions

Prior research has demonstrated that preservice elementary teachers can adapt curriculum to be more inquiry based (Forbes 2011). This study demonstrates that preservice elementary teachers are also able to develop multi-lesson arcs of inquiry-based investigations that engage students in constructing explanations about observational astronomy concepts. Why were these preservice teachers successful? First, many drew from experiences from the methods course where they participated in guided inquiry investigations about astronomy topics. They also adapted aspects of a commercial curriculum read during the course and found new resources online. Teachers who achieved greater content knowledge during the course were also more successful at creating inquiry-based investigations. Finally, the investigation topic may have been a factor: six of the seven pairs that chose to investigate the sun's path (the simplest topic) were classified as developing an inquiry-based investigation (levels 1 and 2).

Most of the preservice teacher pairs that were able to construct a scientific investigation question were also able to use this to engage children with collecting and analyzing data and constructing some form of explanation (even if that was primarily through teacher-led discussion). Groups that were not classified in the more sophisticated levels of inquiry-based investigation plans were not able to connect a clear investigation question with engagement in data collection. This suggests that, in addition to improving their content knowledge, more explicit support on the types of investigation questions that are feasible for elementary astronomy, how to connect that to appropriate data collection methods, and why this is important for learning the practices of science, would be useful in professional development and curricula to support those teachers.

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