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The Impact of a Summer Institute on Inservice Early Childhood Teachers' Knowledge of Earth and Space Science Concepts

Abstract

This study investigated inservice PreK to Grade two teachers' knowledge of some earth and space science concepts before and after a short-term teacher institute. A one-group pre-test-post-test design was used in the current study. Earth science concepts targeted during the professional development included properties of rocks and soils, and the space science concepts included moon shapes and sequences and the cause of moon phases. After the instruction, participants better understood properties of rocks and soil and targeted lunar concepts. They also were able to draw observable moon phases and pattern of changes in phases. The results of the current study indicate that even a short-term professional development enhanced inservice teachers' knowledge of targeted concepts.

Introduction

Most early childhood teachers do not teach science regularly in their classrooms, and when they do teach science, it is often for less than two hours per week (Greenfield, Jirout, Dominguez, Greenberg, Maier, & Fuccilo, 2009; Tilgner, 1990). In a more recent study, the majority of early childhood teachers reported that they teach science once or twice a week with a total of up to 60 minutes of science instruction (Saçkes, Trundle, Bell, & O'Connell, 2011). Early childhood teachers spend less time on science instruction for several reasons, including lack of time, self-confidence, collegial support, materials, money, space, enthusiasm/interest, and content knowledge (Appleton & Kindt, 1999, 2002; Cho, Kim & Choi, 2003).

Key words: inservice early childhood teachers, teacher professional development, earth science, lunar concepts

Lack of content knowledge in science has been reported to be one of the most important reasons that teachers of young children do not teach science (Appleton, 1992; Cho et al., 2003; Harlen, 1997; Tobin, Briscoe, & Holman, 1990). Kallery and Psillos (2001) reported that only about 22% of the early childhood teachers in their study felt that they had sufficient scientific content knowledge. Garbett (2003) found that many early childhood teachers had a limited understanding of the science concepts they are expected to teach, which makes them uncomfortable teaching science, and teachers also reported low confidence in teaching science (Pell & Jarvis, 2003; Tilgner, 1990). Early childhood teachers' lack of confidence in their ability to teach science has been largely attributed to their limited science content knowledge (Appleton, 1995; Schoon & Boone, 1998).

Teachers use a variety of coping strategies to compensate for their lack of science content knowledge including teaching as little of the subject as possible, teaching more biology versus physical science, relying on commercially developed lessons, using non-fiction childrens' trade books, and avoiding all but simple hands-on activities (Akerson, 2004; Harlen, 1997).

Several studies have provided evidence that inservice training can enhance teachers' science content knowledge (Hemler & Repine, 2006; Parker & Heywood, 2000). Parker and Heywood (1998) reported that a ten-day course designed to teach basic astronomy concepts to inservice elementary teachers was effective at improving teachers' knowledge of day and night, seasons, and moon phase concepts. Another ten-day professional development program designed to teach standards-based earth science concepts (e.g. properties and formation of rocks) to nineteen inservice teachers was again effective at improving teachers' knowledge of the related earth science concepts (Trundle, Krissek, & Ucar, 2005). Studies also have shown that in addition to improving teachers' content knowledge, inservice training programs can change teachers' attitude toward science teaching and improve their confidence about science teaching (Jarvis & Pell, 2004). Improved science content knowledge was found to be related to teachers' ability to create inquiry-based science lessons (Luera, Moyer, & Everett, 2005).

Researchers pointed out a need to address science content knowledge during preservice programs and professional development for inservice teachers (Akerson, 2004; Appleton, 1992; Ucar, Trundle, & Krissek, 2006). The current study aimed to address this need through investigating the effects of short-term instruction about earth and space science content for early childhood teachers.

Theoretical Framework

Young children come into our classes with their own ideas about how the natural world works. They likely have their own understandings about the shape of the earth, how rain occurs, why we observe different shapes of the moon, and what makes up rocks and soil. Most of the time these ideas are naïve and non-scientific and often go unarticulated and unchanged in the science classroom if teachers themselves lack scientific understanding of these concepts (Hewson & Hewson, 1988). The *National Science Education Standards* (National Research Council [NRC], 1996) acknowledge the problem of alternative conceptions students have and recommend that teachers address students' misconceptions. However, a review of the literature on lunar concepts shows that students across a wide range of ages and grade levels, including preservice teachers, have difficulty understanding the lunar concepts (Saçkes & Trundle, 2007), and they also have a limited knowledge of rocks and soil (Schoon, 1995; Trundle et al., 2005; Ucar et al., 2006).

Understanding lunar concepts and rocks and soil concepts are part of scientific literacy and are targeted concepts in the *National Science Education Standards* (NRC, 1996) (e.g., patterns of observable moon shape changes and properties of earth materials for grades K-4). Although young children are not expected to understand more sophisticated concepts that follow in the middle grades like cause of the lunar phases and how rocks and soils form, preservice and inservice early childhood teachers who themselves hold alternative conceptions about these concepts can present a serious problem for instruction. Teachers' alternative conceptions may hinder their presentations of basic concepts that lead to the understanding of the cause of the lunar phases and the formation of earth materials. If elementary and early childhood teachers are expected to teach their students about the foundational concepts of earth materials and lunar concepts, it is reasonable to expect teachers to have a scientific understanding which extends well beyond what they are expected to teach. Thus, targeting inservice teachers' content knowledge of these concepts makes logical professional sense. The *Atlas of Scientific Literacy* (American Association for the Advancement of Science [AAAS], 2001) suggests that basic concepts (e.g., the appearance of the moon changes every day, the moon can be observed sometimes at night and sometimes during the day, and objects in the sky appear to move slowly) lay the foundation for understanding more advanced concepts in later grades (e.g., the moon's orbit around the earth and the cause of the moon phases). Likewise, children's observations of properties of different types of rocks and soils lay a foundation for their understanding of more advanced earth science concepts, such as the formation of rocks and soils, weathering, and erosion. Without instruction to help inservice teachers develop a scientific understanding of basic concepts of rocks, soils, and the moon, the potential exists that they will not recognize misconceptions their students have about those basic concepts and they may mislead students in the early childhood grades of PreK to grade two. Improving teachers' content knowledge may enhance their attitude toward and confidence about teaching science and improve their science teaching practices (Jarvis & Pell, 2004; Luera et al., 2005; Schoon & Boone 1998).

The present study is based on conceptual change theory, which posits that learners come into science classes with preconceptions, which may include misconceptions (Duit & Treagust, 1995; Vosniadou, 1994). Research studies, which documented alternative conceptions of learners in various domains, revealed that alternative conceptions are often pervasive and resistant to change through traditional forms of instruction (Driver, Guesne, & Tiberghien, 1985; Gilbert & Watts, 1983). For many researchers this resistance to change is due to alternative conceptions being embedded in organized cognitive structures and reinforced by everyday experiences (Vosniadou, 1994, 2002). The current study is based on the model of framework theorists who define conceptual change as the gradual modification of existing mental models (Vosniadou, 1991; 1994; Vosniadou & Brewer, 1992). "Mental models are analog representations that preserve the structure of the thing they represent" (Vosniaodu, 2002, p.356). Mental models can aid in the construction of an explanation and work as mediators in the interpretation and acquisition of new information. Through instruction learners' initial mental models are transformed into synthetic models or scientific models.

Mental models are constructed based on the *specific theory*, which includes "a set of interrelated propositions or beliefs that describe the properties and behavior of physical objects" (Vosniadou, 1994, p.47). Specific theories that include foundational concepts of astronomy and earth materials would facilitate children's learning of more advanced concepts and their construction of scientific mental models in upper grades. Teachers with solid scientific content knowledge might be more likely to help children developing specific theories that facilitate their understanding of more advanced scientific concepts.

The current study utilizes a professional development context designed to improve inservice teachers' content knowledge of targeted earth and space science concepts and to address the misconceptions they may have, hopefully increasing the likelihood of teachers detecting and targeting their students' misconceptions in the future.

Purpose

The purpose of this study was to investigate the effects of a teacher institute on inservice PreK to Grade two teachers' knowledge of earth and space science concepts (rocks, soils, lunar concepts) they are expected to teach. While previous studies have focused mostly on preservice teachers, studies that focused on inservice teachers targeted teachers of upper grades with a relatively longer-term instruction than the current study (Trundle et al., 2005; Parker & Heywood, 1998). The present study aimed to improve inservice early childhood teachers' knowledge of earth and space science concepts they are expected to teach through an intervention that lasted only four days.

Methodology

Design.

A one-group pre-test-post-test design was used in the current study (Cook & Campbell, 1979). Participants were tested before and immediately after the instruction. There was no control group in the study due to the nature of the study setting.

Setting.

The research took place in a teacher institute, which was a collaborative effort between the College of Education, the College of the Arts and Sciences, and the State Department of Education. Participants were enrolled in an institute that aimed to enhance PreK through grade two teachers' knowledge of science and mathematics content for their grade levels. Earth science concepts targeted during the institute included properties of rocks and soils. The earth science instruction took place over two days, with six hours each day being devoted to instruction with a total of 12 hours of instruction. The space science concepts targeted during the institute included moon shapes and sequences and the cause of moon phases. The space science instruction took place over one and a half days, at six hours per day for a total of nine hours of instruction, which involved the teachers gathering and analyzing observational moon data.

Instruction in pedagogy focused on inquiry-based instruction and hands-on learning. The instruction on earth science concepts targeted properties of rocks and soils and consisted of three parts: identifying and describing common minerals and rocks, properties of soils, and common fossils. Rocks and minerals sets were distributed to the participants, and participants were asked to explore and describe properties of different rocks and minerals. The distinctions between rocks and minerals were discussed and properties of rocks and minerals were explored in small groups. Participants keep a geology laboratory notebook and recorded the properties of rocks and minerals they observed. Differences and similarities between the properties scientists use to distinguish and identify rocks and the properties participants proposed were compared and discussed. Participants were asked to bring soil samples to the class. Three types of soil samples were also provided to participants in the class. Participants explored the soil samples and recorded their observations. Properties of soil and similarities and differences between different soil samples were discussed. An optional field trip was made to a local fossil site. Participants collected fossil samples and recorded their observation of the fossil site in their geology laboratory notebook. Additional fossil samples were provided to participants in the class. The formation of fossils and the information they present to scientists was discussed. Teachers used the fossils to interpret changes in the environment. A summary of the earth science instructional activities can be found in Table 1.

The instruction that targeted lunar concepts integrated the *Starry Night Backyard* software with instruction on moon phases from *Physics by Inquiry* by McDermott (1996). *Starry Night Backyard* was used in several studies to support conceptual change learning including studies with preservice teachers (Bell & Trundle, 2008) and children in lower elementary grades (Hobson, Trundle, & Saçkes, 2009). These studies showed that even children in lower elementary grades can

Table 1. Summary of Instructional Activities for Earth Science

Targeted Concepts	Summary of Activities
Identifying and describing common minerals and rocks	1. Explore rocks and minerals set. 2. Describe properties of rocks and minerals. 3. Record observations of rocks and minerals. 4. Identify the similarities and difference between different rocks and minerals. 5. Recognize the properties scientists use to identify and distinguish rocks and minerals.
Identifying and describing properties of soils	1. Explore soil samples. 2. Describe properties of different soil types. 3. Record observable properties of soil samples. 4. Identify the similarities and difference between different soil samples. 5. Recognize the properties scientists use to identify and distinguish soils.
Identifying, describing, and interpreting common fossils	1. Collect fossil samples from a local fossil site. 2. Identify common fossils using tools. 3. Interpret environmental changes based on the fossil record.

use the software independently to collect moon data (Hobson et al., 2009). The instruction was identical to that of previous investigations (Trundle, Atwood, & Christopher, 2002, 2006, 2007a, b, 2010) with a few minor differences. Inservice teachers' moon observations were collected from the *Starry Night Backyard* software rather than actual observations of the moon and the instruction took place over one and a half days with a total of nine hours rather than being spread out over a four week period. The instruction consisted of three parts: (1) gathering, recording, and sharing moon data, (2) analyzing moon data by looking for patterns in the data, and (3) modeling the cause of moon phases. A summary of the instructional activities can be found in Table 2.

Data from the teachers were gathered during the first week of the summer institute, which comprised the earth and space science part of the institute.

Participants.

Twenty-five inservice early childhood education teachers employed in four central Ohio school districts were the participants of the study. All participants were female. The majority was White (84%) and four participants (16%) were Black. Most were regular classroom teachers (88%) and the others were special education, resource, or inclusion teachers (12%). All of the participants taught PreK through grade two. Thirty-six percent of the teachers had less than six years of experience as a classroom teacher, including three teachers (12%) who had less than three years of experience. Sixty-four percent had six or more years of teaching experience. All of the participants of the summer institute gave their consent to participate in the study.

Researchers.

The three members of the research team included a science educator and a geologist who worked together to design and teach the earth and space science part of the institute. The third member was a doctoral student in early childhood science education. The geologist provided the instruction for the earth science concepts, and the science educator conducted the instruction for the space science concepts. All team members gathered, coded, and analyzed all data.

Data collection and analysis.

The Geology Content Knowledge Assessment (GCKA) was used to measure participants' knowledge of the earth science concepts. The GCKA is comprised of 56 multiple choice and short answer questions developed to measure teachers' knowledge of the

Table 2. Summary of Instructional Activities for Space Science*

Targeted Concepts	Summary of Activities
Identifying observable patterns	1. Identify and describe patterns. 2. Describe rate of change (i.e., gradual or abrupt). 3. Draw an observed sequence of moon shapes. 4. Identify when the sky was clear but the moon could not be observed.
Determining the length of the cycle	1. Number data from day 1 to day 63. 2. Select a distinctive shape. 3. List the number of the day that the shape first appeared. 4. List the number of the second and third days when the shape reappeared. 5. Repeat with 3 additional shapes. 6. Estimate how much time passed before each shape reappeared.
Sequencing the observed shapes	1. Sequence a series of drawings of 8 representative phases in the pattern observed.
Applying new concepts and scientific labels	1. Use the scientific term "new moon" to describe when the moon could not be observed during the moon cycle. 2. Use the scientific term "synodic period" to describe the time interval from new moon to full moon and back to new moon. 3. Apply scientific labels (e.g., waxing gibbous) to each shape.
Modeling the cause of moon phases	1. Participate in a psychomotor modeling activity by first darkening a room. 2. Place a bright, exposed light bulb at eye level to represent the sun. 3. Use a Styrofoam ball as a model for the moon. 4. Hold the ball in front of body at arm's length. 5. The student's head is the earth. 6. Move the ball around their heads. 7. Note the appearance of the lit portion of the ball. 8. Determine how much of the moon is lit at any one time 9. Use the models to reproduce all the phases in the order they were observed. 10. Write and orally explain their understandings of the causes of moon phases.

* Bell & Trundle (2008). Journal of Research in Science Teaching.

standards-based concepts they are expected to teach. A panel of experts consisting of two science educators, a geologist, and several science education graduate students established content validity of the GCKA. Coefficient of stability was .81 (Beifuss, Krissek, Boone, Trundle, White, & Ucar, 2005). In the current study 13 items from the GCKA that correspond to the targeted earth science concepts included in the institute were used to measure participants' knowledge of the standards-based concepts. The GCKA was administered before and immediately after the instruction. It took approximately ten minutes to complete the instrument in both administrations. Internal reliability of the GCKA in this study, Cronbach's alpha, was .58. This low reliability of the measure might be due to lower number of items (Hatcher & Stepanski, 1994; Kehoe, 1997).

The Earth Science Survey (Ucar et al., 2006) was given to participants to reveal what the teachers knew about the properties of rocks and soil, whether they had taught these concepts before, and their plans to teach them in the future. The survey consisted of eight open-ended questions and was administered before and immediately after instruction.

The Lunar Phases Concept Inventory (LPCI) was used to measure participants' knowledge of the lunar concepts. The LPCI is a multiple-choice instrument developed to assess college students' knowledge of lunar phases (Lindell, 2001). The distracters of each item were based on common misconceptions described in the lunar literature. The LPCI's content validity was established by a panel of six experts consisting of two physics educators, two astronomers, and two astronomy educators. Internal reliability of the LPCI was .54. In another study internal reliability was reported as .55 for the pre-test measure and .75 for the post-test measure (Lindell & Olsen 2002). In the present study, 13 items from the LPCI that corresponded to the targeted lunar concepts in the institute were used to measure participants' knowledge of the standards-based concepts. The internal reliability coefficient of LPCI, Cronbach's alpha, was .64 in the current study. The LPCI was administered before and immediately after the instruction. It took approximately ten to 15 minutes to complete the instrument in both administrations.

Participants also were asked to draw the phases of the moon and the observed sequence before and after instruction. The *Moon Drawing* test, developed by Trundle and colleagues (2006), included three tasks: 1) predict and draw the appearance of all moon shapes or phases they would observe; 2) predict if different moon phases appear in a recurring sequence; and 3) draw the phases in the patterns they expect to observe them. The same tasks were used in both the pre- and post-test drawings with only minor changes in post-test prompts, which referred to the observations participants had made during the instruction.

To determine the effectiveness of the short-term instruction on inservice teachers' knowledge of earth science concepts and the lunar concepts, statistical comparisons were made of both participants' individual pre-test and post-test scores using the paired sample t-test statistic. Participants' responses to Earth Science Survey questions were examined to reveal their understanding of the properties of rocks and soils and whether they intended to teach these concepts and how they were planning to teach them. Participants' responses to individual GCKA and LPCI items were also analyzed to gain deeper understanding of shifts in content knowledge. To determine participants' knowledge of observable moon phases and the pattern of change in phases the pre- and post-test drawings made by the participants were coded and analyzed using a coding sheet based on previous research (Trundle et al., 2006). A member of the research team analyzed and coded all drawings. Another member of the research team also analyzed 30% of randomly chosen drawings to establish inter-rater reliability. Inter-rater agreements between the two codings were 85% for the pre-test drawings and 97% for the post-test drawings.

Findings

GCKA and LPCI results.

Participants' pre- and post-test scores obtained from the GCKA were analyzed to see if there was a significant difference between the post-test scores compared to pre-test scores. The paired-sample t-test analysis indicated that for the 25 participants, the mean score on the post-test ($\bar{x}$ =9.28, sd=2.07) was significantly higher ($t(24)=5.506$, $p<.001$) than the mean score on the pre-test ($\bar{x}$=6.88, sd=2.22). Researchers suggest reporting effect size indices as it enhances the interpretation of the results of the statistical analysis (Rosnow & Rosenthal, 1996). The effect size indices assess the magnitude of the treatment effect and are calculated by dividing the difference of the group means by the pooled standard deviation. Cohen's (1988) d, one of the most popular effect size indices, is calculated and reported for all the parametric statistical analysis in this study. Cohen suggested that effect size of d=0.2 should be considered as low effect, d=0.5 should be considered as medium effect and d=0.8 or higher should be considered as large effect. For the analysis of GCKA scores the effect size was medium, d=0.52, suggesting instruction had a moderate impact on the participants' GCKA scores.

Participants' pre- and post-test scores obtained through LPCI were analyzed to see if there was a significant increase in the post-test scores compared to the pre-test score. The paired-samples t-test analysis indicated that for the 25 participants, the mean score on the post-test ($\bar{x}$ =10.40, sd=1.936) was significantly higher (t(24)= 9.927, p<.001) than the mean score on the pre-test ($\bar{x}$ =6.24, sd=2.278). The effect size was impressively large, d=1.97, suggesting instruction had a very large impact on participants' LPCI scores.

Analysis of the earth science survey.

Figure 1 shows the properties of rocks indicated by the participants on the earth science survey before and after the instruction. Participants indicated a wide range of distinct properties of rocks in the pre-test, including some that are distinctly non-scientific (e.g., size and shape). Eight participants indicated "no understanding" of the distinct properties of rocks. The most commonly indicated properties of rocks were "hardness" (ten responses), "texture" (11) and "color" (12) in the pre-test.

In the post-test, all participants mentioned at least one property of rocks. The most commonly indicated properties of rocks were "hardness" (nine responses), "mineral content" (ten), "texture" (16), "color" (18), "origin" (15), and "layering" (seven) in the post-test.

The mean numbers of properties of rocks indicated by the participants on the pre- and post-test were compared to see if there is a difference in the number of properties indicated between the pre- and post-test. The paired-sample t-test analysis showed that for the 25 participants, the mean number of properties of rocks indicated by the participants on the post-test ($\bar{x}$=3.92, sd=1.85) was significantly higher (t(24)=2.41, p<.05) than the mean number of properties indicated on the pre-test ($\bar{x}$=2.64, sd=2.01). The effect size was medium, d=0.66, indicating the instruction moderately influenced the participants' knowledge of the properties of rocks.

Figure 1. Properties of rocks indicated by the participants on the earth science survey.

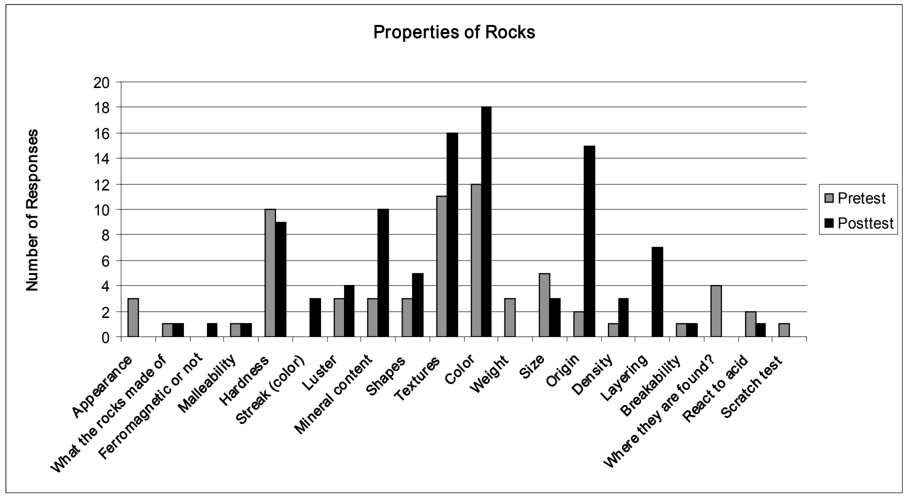


Figure 2. Properties of soil indicated by the participants on the earth science survey.

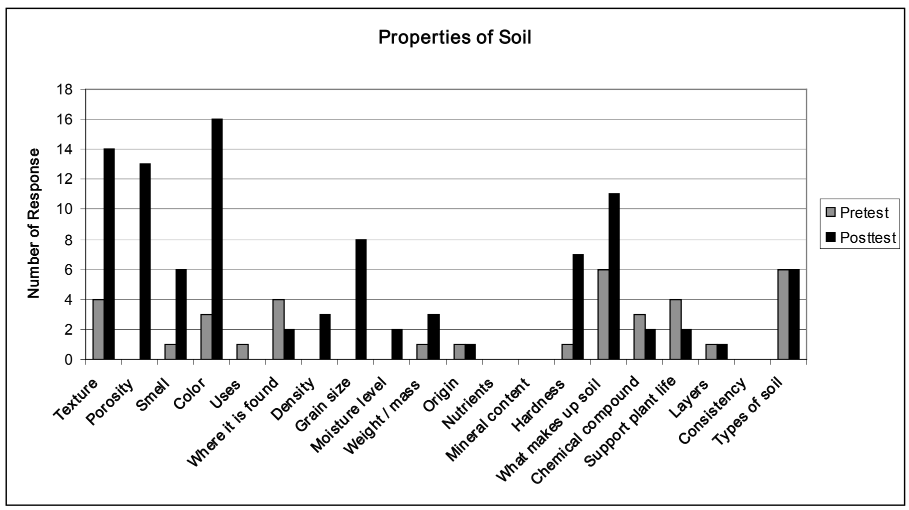


Figure 2 shows the properties of soil indicated by the participants on the earth science survey before and after the instruction. Participants indicated a wide range of distinct properties of soil in the pre-test, including some that are distinctly non-scientific (e.g., weight? and mass?). Seven participants indicated "no understanding" of the distinct properties of soil. The most commonly indicated properties of soil were "texture" (four responses), "where it is found" (four), "what makes up soil" (six), "support plant life" (four) and "types of soil" (six) in the pre-test.

In the post-test, all participants mentioned at least one property of soil. The most commonly indicated properties of soil were "texture" (14 responses), "porosity" (13), "smell" (six), "color" (16), "grain size" (eight), "hardness" (seven), "what makes up soil" (11) and "types of soil" (six) in the post-test.

The mean numbers of properties of soil indicated by the participants on the pre- and post-test were compared to see if there is a difference in the number of properties indicated between the pre- and post-test. The paired-sample t-test analysis showed that for the 25 participants, the mean number of properties of rocks indicated by the participants on the post-test ($\bar{x}$=3.88, sd=1.62) was significantly higher (t(24)= 6.03, p<.001) than the mean number of properties indicated on the pre-test ($\bar{x}$=1.44, sd=1.19). The effect size was quite large, d=1.72, suggesting instructional intervention had a high impact on the participants' knowledge of the properties of soil.

Participants also indicated whether they had taught about the properties of rocks and soil before, and their plans to teach about them in the future. Before the instruction nine participants indicated that they taught about the properties of rocks before. While the number of participants who indicated that they were planning to teach about the properties of rocks in future was nine before the instruction, 19 participants indicated that they were going to teach about the properties of rocks in their classroom after the instruction. Six teachers indicated that they were planning to use an inquiry-based approach to teach about the properties of rocks before the instruction. The number of teacher who planned to use an inquiry based approach to teach about properties of rocks increased to 15.

Before the instruction five participants indicated that they taught about the properties of soil before. While the number of participants who indicated that they were planning to teach about the properties of soil in future was 21 before the instruction, all of the participants indicated that they were going to teach about the properties of soil in their classroom after the instruction. Six teachers indicated that they were planning to use an inquiry-based approach to teach about the properties of soil before the instruction. The number of teacher who planned to use inquiry based approach to teach about properties of soil increased to 12.

Analysis of the GCKA and LPCI items.

Figure 3 shows the number of correct response for each item for GCKA before and after the instruction. A deeper analysis of the GCKA items showed that before the instruction item number two, eight, 12 and 13 had the least number of correct responses. Item two deals with fossils, specifically the earth's oldest fossils. Item eight deals with types of rocks and asks to identify what types of rocks are the ice in an ice cube and ice in a glacier. Item 12 deals with the properties of rocks and asks what the term "cleavage" is used to identify. Item 13 deals with rock formation and asks the type of the rocks that is most likely to have formed by accumulating fossil shells. After the instruction, the number of correct responses increased for almost all the items, except for item two and with a minor decrease for item three. Twenty-three participants mistakenly chose "marine invertebrates" as the response for item two where the correct response was "bacteria." "Marine invertebrates" was the correct response for item four, which also deals with fossils and was answered correctly by all participants. The decrease in the number of correct response in item two in post-test might have been due to participants confusing these two items.

Figure 3. Participants' responses to the individual GCKA items.

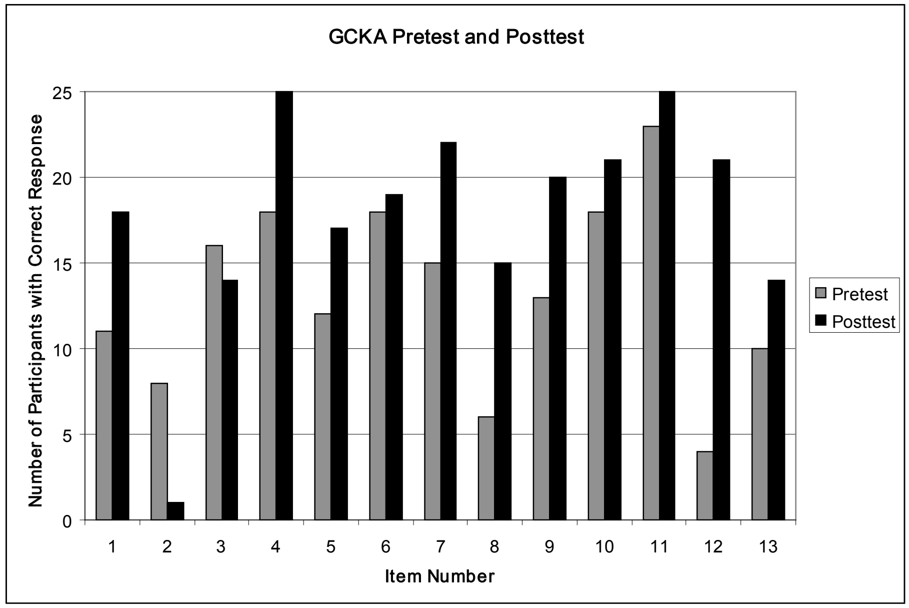
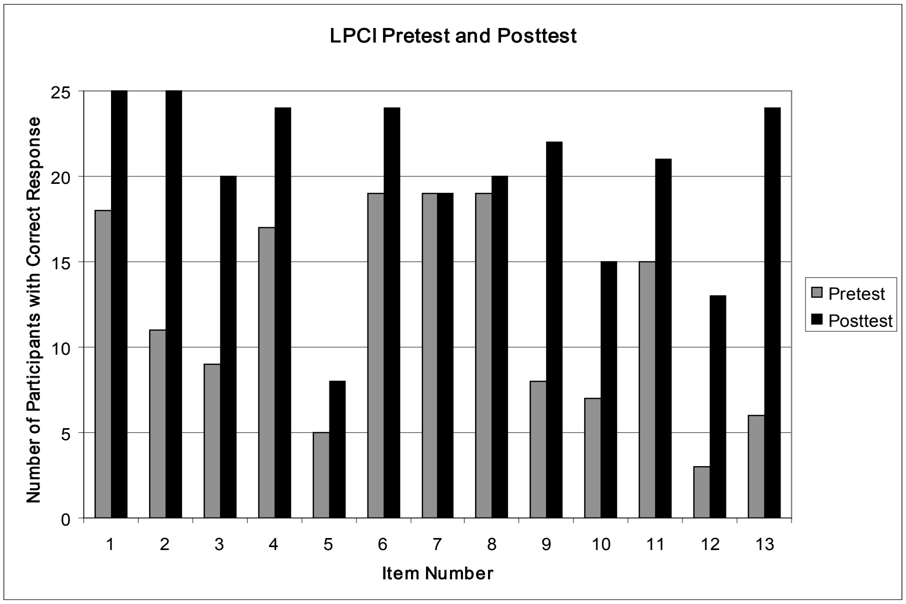


Figure 4, on the next page, shows the number of correct responses for each item for LPCI before and after the instruction. A deeper analysis of the LPCI items showed that before the instruction only six items (one, four, six, seven, eight, and 11) were correctly answered by more than half of the participants. These items deal with the time and orbit (one, four, seven, and 11) and shape and sequence (six and eight). Participants had difficulty with items that deal with time and orbit (two), shape and sequence (five, nine and ten) and cause of the moon phases (three, 12 and 13).

In general, participants were less successful on the LPCI than the GCKA in the pre-test. The cause of the moon phases was the least understood concept by the participants in the pre-test. All of the items that dealt with the cause of the moon phases were correctly answered by less than half of the participants in the pre-test. Participants generally chose alternative explanations over a scientific explanation for the cause of the moon phases. For example, 56% of the participants for the item three, 60% of the participants for the item 12, and

Figure 4. Participants' responses to the individual LPCI items.



64% of the participants for the item 13 chose the eclipse model (the shadow of the Earth causes the moon phases) for the cause of the moon phases in the pre-test. These results are aligned with the lunar literature, which indicates that the cause of the moon phases is one of the scientific concepts learners have more difficulty with understanding, and the eclipse model is the most common alternative conception learners are likely to have.

After the instruction, almost all of the items were correctly answered by more than half of the participants, with the exception of item five, which asks the phase of the moon during solar eclipse. Other items that deal with shape and sequence concepts were correctly answered by more than three-fourths of the participants in the post-test. Of the items that deal with time and orbit, two were answered by the all of the participants (one and two) and the remaining were answered by more than three-fourths of the participants in the post-test (four, seven and 11). In contrast to pre-test, items dealing with cause of the moon phases were correctly answered by more than three-fourths of the participants (three and 13), with the exception of item 12. Almost half of the participants chose alternative explanation over scientific explanation for the cause of the moon phases in item 12. Again eclipse model was the most popular alternative explanation among the participants who failed to choose scientific explanation for the cause of the moon phases. Cross examination of the those participants who chose alternative explanation for item 12 in post-test revealed that four participants consistently chose the eclipse model for other items that deal with the cause of the moon phases in both the pre-test and the post-test. It appears that instruction had little impact on transforming those four participants' initial mental models of the cause of the moon phases.

Analysis of the moon drawings.

Before instruction, almost all of the participants (96%) included alternative, non-scientific shapes in their moon drawings and drew moon phase sequences that are non-scientific (Table 3). Only one participant drew scientific moon phases and sequences (4%). After instruction, a majority of the participants drew scientific moon phases (68%), and moon phase sequences (68%). Over half of the participants were able to draw both scientific phases and scientific sequences (52%).

A nonparametric statistical test, the McNemar test for two related samples, was used to examine the numbers of participants who shifted in content knowledge from nonscientific or scientific drawings from pre- to the post-test drawing. Results indicated that significantly more participants shifted from drawing nonscientific shapes on the pre-test to drawing scientific shapes on the post-test ($p<.001$). Results for the sequences were similar in that significantly more participants shifted from drawing alternative waxing and waning sequences on the pre-test to drawing scientific sequences on the post-test ($p<.001$). Also, significantly more participants shifted from drawing both nonscientific shapes and sequences on the pre-test to drawing both scientific shapes and sequences after instruction ($p=.001$).

Table 3. Gains from Pre-test to Post-test for Drawings of Shapes and Sequences

Participants' drawings consisted of:	Pre-test	Post-test	Gain (Post-test-Pre-test)
Scientific moon phases	4%	68%	64%
Scientific waning and waxing sequences	4%	68%	64%
Scientific phases and sequences	4%	52%	48%

Discussion

The present study sought to investigate inservice early childhood teachers' knowledge of earth materials and lunar concepts including properties of rocks and soils, the cause of the moon phases and patterns of moon shapes and sequences. After the instruction, participants not only understood the lunar concepts but also were able to draw more scientific representations of observable moon phases and the pattern of changes in phases. After the instruction, the participants' content knowledge of rocks and soils also increased; they were able to indicate more properties of rocks and soils, and they included more scientifically accurate responses. Teachers must help children develop accurate conceptions of foundational concepts related to earth materials and objects in the sky like the moon in order to facilitate children's learning of more advanced concepts in later grades like the cause of the lunar phases and the formation of rocks and soils. Thus, it is critical that teachers understand the basic concepts and related phenomena themselves. In other words, teachers need to know more content than they are expected to teach. Teachers' understandings of advanced earth and space science concepts may allow them to see connections between foundational concepts they are expected to teach in lower elementary grades and the concepts their students will learn in upper elementary grades and beyond (AAAS, 2001).

The results of the current study indicate that even a short-term professional development that addressed earth materials and lunar concepts seemed to enhance inservice teachers' knowledge of these concepts. Professional development opportunities that improve inservice early childhood teachers' science content knowledge, like the one reported here, offer the promise to eliminate one of the obstacles that can impede early childhood teachers teaching of at early grades. Indeed, while the number of participants who indicated that they are planning to teach about the properties of rocks and soil in the future was nine and 21 respectively before the instruction, 19 participants indicated that they are going to teach about the properties of rocks and all of the participants indicated that they are going to teach about the properties of soil in their classroom after the instruction.

Improved content knowledge may also help teachers to identify and challenge their students' preconceived ideas or misconceptions (Smith & Neale, 1989), and develop inquiry-based lessons to address those misconceptions (Luera, et al., 2005). Six teachers indicated that they were planning to use an inquiry-based approach to teach about the properties of rocks and soil before the instruction. The number of teacher who planned to use an inquiry-based approach to teach about properties of rocks and soils increased to 15 and 12 respectively.

We compared the result of the present study with the results of previous studies on preservice teachers' knowledge of lunar concepts (Bell & Trundle, 2008; Trundle et al., 2002, 2006, 2007a). In the present study, the gains in knowledge from pre- to post-instruction are very positive although they are slightly lower than the gains reported in previous studies. This difference may be due to the limited time (1.5 days) devoted to the instruction in the current study. Although the gains in content knowledge are slightly lower in the current study compared to the gains obtained in the studies where long-term instructional interventions were implemented, our results are still impressive given the relatively short amount of time devoted to the instruction. These results are encouraging given that many teacher institutes are limited by the amount of time teachers are available for instruction. Our results suggest that short-term instruction could be a good trade off considering the time versus gain ratio.

There are several limitations of the current study. Participants self-selected to participate in the teacher institute. Results might have been different if the participants were randomly selected to participate. If an institute could consist of inservice teachers who did not volunteer to participate but who were required to complete the professional development, the results obtained in this study might not be replicated. To measure participants' content knowledge, multiple-choice instruments were used in the current study. Previous studies have shown that multiple-choice instruments tend to overestimate participants' conceptual understanding (Trundle et al., 2002, 2010). Semi-structured interviews might have produced different results. The present study did not have a control group due to nature of the study setting and time constraints. Therefore, we had no means to control confounding variables such as testing effect. Future studies should use a research design with a control group and randomly selected participants if possible. Future studies might use a shortened version of the semi-structured interview protocol used in previous studies to measure participants' conceptual understanding of lunar concepts (Trundle et al., 2002, 2007a). This study provided strong evidence that short-term instruction had a moderate to very large effect on inservice teachers' content knowledge of rocks and soils, and lunar concepts. Future studies should include delayed-post measure in their design to assess the durability of the gains in content knowledge.

The study of earth and space science has increased in importance as reflected in recent versions of national and state science standards. The teacher institute described in this study sought to provide opportunities for teachers to improve their standards-based content knowledge and skills for teaching earth and space science content. In order for teachers to help students develop accurate conceptions about the earth materials and lunar concepts, it is critical that they understand the phenomena themselves. Documenting their understanding and evaluating instructional strategies to address early childhood teachers' content knowledge can help inform the practice of science teacher educators and scientists who work with inservice and presevice teachers.

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