

Preservice Elementary Teachers' Knowledge of Observable Moon Phases and Pattern of Change in Phases

Kathy Cabe Trundle

College of Education, The Ohio State University, Columbus, OH 43210-1172 U.S.A.

Ronald K. Atwood

College of Education, University of Kentucky, Lexington, KY 40506 U.S.A.

John E. Christopher

College of Arts and Sciences, University of Kentucky, Lexington, KY 40506 U.S.A.

Published Online: 4 August 2006

The purpose of this study was to describe selected content knowledge held by 52 preservice elementary teachers about the observable phases of the moon and the monthly pattern of change in observable phases. Data were obtained from participants in a physics course before and after they received inquiry-based instruction designed to promote intentional learning of the cause of moon phases and the observable pattern of change in moon phases. Results indicated that, prior to instruction, most preservice teachers had major deficiencies in knowledge of observable moon phases and the pattern of monthly change in the phases. Fortunately, participants who completed the instruction were likely to show evidence of having addressed the deficiencies.

Introduction

Astronomy, often called the oldest science, fascinates and inspires wonder in almost everyone. Throughout history, Earth dwellers have marveled as the moon waxed from a new moon to a full moon and then waned back to a new moon. Early astronomers realized that the phases of the moon occur in a regular, predictable cycle. This understanding was used to develop the first calendars, and the word *month* is derived from *moon*. Although changes in the appearance of the moon are a familiar natural phenomenon, it seems unlikely the masses of people have engaged in systematic observation of the moon over time and serious analysis of observational data for patterns. Thus, a lack of knowledge of specific observable moon phases and pattern of change in the phases may be widespread.

Understanding lunar concepts is a part of scientific literacy targeted in the National Science Education Standards (National Research Council, 1996). More specifically, for grades K–4, students are expected to study the patterns of movement and observable shape changes in the moon. Explaining the cause of moon phases is an expectation for grades 5–8. As the National Science Education Standards document further states:

By observing the day and night sky regularly, children in Grades K–4 will learn to identify sequences of changes and to look for patterns in these changes. . . . They can draw the moon’s shape for each evening on a calendar and then determine the pattern in the phases over several weeks. These understandings should be confined to observations, descriptions, and finding patterns. (pp. 131, 133)

In preparing these statements, the developers of the standards seemed to assume observing, describing, and finding patterns in moon shapes, or phases, to be less conceptually demanding and more developmentally appropriate for younger children than explaining the cause of moon phases. On the face of it, such an assumption appears reasonable, since being able to describe observable phases and sequences could be only a matter of recall.

Conceptual understanding about the moon, including alternative conceptions, has interested researchers for many years (Cohen & Kagan, 1979; Jones & Lynch, 1987; Treagust, 1988). Most previous research about the moon has been descriptive and limited to identifying alternative conceptions (Baxter, 1989; Bisard, Aron, Francek, & Nelson, 1994; Dai & Capie, 1990; Haupt, 1950; Kuethe, 1963; Schoon, 1992, 1995). However, a review of the literature revealed eight studies that addressed the effects of instructional strategies on students’ understanding of the cause of moon phases (Abell, George, & Martini, 2002; Barnett & Morran, 2002; Callison & Wright, 1993; Sadler, 1987; Stahly, Krockover, & Shepardson, 1999; Targan, 1988; Trundle, Atwood, & Christopher, 2002; Zeilik, Schau, & Mattern, 1999). Five of the eight studies dealt with the conceptual understandings of college students, including preservice teachers (Abell et al., Callison & Wright; Targan; Trundle et al., Zeilik et al.). The remaining three studies focused on elementary school students (Barnett & Morran; Stahly et al.) and high school students (Sadler). The results of these studies indicate that most preservice teachers, like the students they are preparing to teach, do not understand the cause of moon phases.

Only the study by Stahly and her colleagues (1999) examined instructional effects on a small group of elementary students in the K–4 range. More specifically, the conceptual understanding of four third-grade students was assessed on a pre- and postbasis, utilizing individual interviews and observations to gather data. Their study focused on the cause of moon phases and seemed to emphasize Earth-Sun-Moon relationships, rather than describing observed phases and identifying patterns in the observed phases. In fact, there is no indication their instructional intervention included direct observations of moon phases by the students over time. The study of 14 advanced grade-five students by Barnett and Moran (2002) emphasized the positions of the Earth, Sun, and Moon associated with various moon phases and lunar and solar eclipses. No previous research on K–4 children or on preservice teachers preparing to teach K–4 children has focused on ability to describe and identify observable moon phases and observable patterns of change in moon phases before and after instruction.

Purpose of Study

Educators are charged with helping develop a scientifically literate society. If teachers hold a nonscientific understanding of the science content they are expected to teach, they are unlikely to meet their instructional responsibilities for the content. If K–4 elementary teachers are expected to teach about observable moon phases and patterns of change in the phases, they should be able to describe the phases and patterns of change in phases themselves. If teacher education programs are not preparing K–4 teachers to demonstrate this ability, the programs are failing to prepare teachers to meet their instructional responsibilities. Therefore, documentation of preservice K–4 teachers' limitations in understanding this content before and after instruction will help inform the practice of science teacher educators. The present study was designed to serve that purpose and provide the needed documentation.

The following research questions guided the study:

1. Are preservice elementary teachers' knowledgeable about observable moon phases and the regularly recurring pattern of change in phases before instruction designed to provide this knowledge?
2. After completing special instruction, how does the knowledge of preservice elementary teachers about observable moon phases and the regularly recurring pattern of change in phases compare to preinstruction knowledge?

Methodology

The qualitative design (Glesne & Peshkin, 1992; Mason, 1996) of the study used drawings by preservice teachers as a data source to assess their knowledge before and after instruction. In analyzing the drawings, attention was given to the phases drawn and the sequence in which the phases were drawn. The primary interest was in determining whether the phases and sequences drawn were observable and therefore scientific representations.

Participants and Setting

Participants were 52 preservice elementary teachers enrolled in an inquiry-based physics course at a research university in the southeastern United States. Participants' ranged in age from 20 to 49 years, with a mean of 24.2 ($SD = 6.2$) years. Ninety-six percent were female; 98% were Caucasian, and 2% were African American.

Roles of Researchers

The research team included one physics professor and two science educators. The physics professor, John Christopher, taught the course that included the intervention instruction. One science educator, Kathy Cabe Trundle, served as principal investigator and a participant observer in the physics course. In collaboration with

the physics professor, she also served as the data collector (Glesne & Peshkin, 1992). The three researchers independently analyzed all student drawings.

Data Collection

Previous research has revealed that drawings can be used to provide rich data on participants' understanding of science concepts and reveal alternative conceptions (Coates, 2002; Cuthbert, 2000; Dove, Everett, & Preece, 1999; Edens & Potter, 2003; Golomb, 1992; Hayes, Symington, & Martin, 1994; Moline, 1995; Rennie & Jarvis, 1995; Strommen, 1995; Van Meter, 2001; White & Gunstone, 1992). Some concepts (e.g., cloud types, leaf shapes) are more easily communicated through drawings than written descriptions (Dove et al., 1999).

Pre- and postinstructional drawings made by the 52 participants were included in the qualitative design (Glesne & Peshkin, 1992; Mason, 1996; Rubin & Rubin, 1995). The drawings were analyzed to determine participants' knowledge of regularly observable moon phases and the pattern of change in phases. Data-gathering tasks were based on previous research (Trundle et al., 2002). The three tasks are described in Table 1. In preparation for the preinstruction tasks, students were asked to recall observations revealing that the moon doesn't always look the same. They were reminded that the moon sometimes appears full and sometimes the moon does not appear full, and the different observable shapes of the moon are called phases. Then participants were told that, when possible, they would be making daily moon observations during the semester. In Task 1, participants were asked to predict the appearance of all moon shapes, or phases, they would observe. As a mechanism for recording predictions, participants were asked to draw a full moon and all other phases they would expect to observe during the upcoming observations. In Task 2, participants were asked whether they would expect different moon phases to appear in a predictable sequence. They recorded their response by circling "yes" or "no" on the data sheet. For Task 3, participants who indicated they expected the moon

Table 1
Description of Tasks

Task	Pretest description	Posttest description	Targeted content
1	Draw all moon phases you expect to observe.	Draw all the phases you observed.	Observable phases of the moon
2	Predict whether the moon phases will appear in a predictable sequence or pattern.	Did the moon phases appear in a predictable sequence or pattern?	Monthly pattern of change in observable phases
3	Draw the phases in the pattern you expect to observe.	Draw the phases in the pattern you observed.	Monthly pattern of change in observable phases

phases to appear in a predictable sequence were asked to draw the phases in the pattern they expected to observe.

Fourteen weeks later, with only minor changes, the same tasks were used during postinstruction data gathering. The minor change in Task 1 was to refer to the observations participants had made during the semester and ask them to draw a full moon and all other moon phases they had observed during the weeks of data gathering. For Task 2, participants were asked if they thought moon phases appeared in a predictable sequence. If they responded "yes," for Task 3, they were asked to draw the moon phases in the sequence they had observed.

Instructional Context

Participants were taught about the moon as part of an undergraduate physics course designed for, and limited to, preservice elementary teachers. Since the participants were preservice teachers who were enrolled in the physics course, they also are called "students." In studying the moon, students made and discussed observations while working in groups of three. The students' in-class work was based on instructional materials from *Physics by Inquiry* (McDermott, 1996).

Highlights of instruction provided on moon phases follow. On the first day of class, students were given a three-page chart with squares arranged on each page in calendar form. The squares were numbered to correspond to days in the semester. Students were asked to record results of making a moon observation in a square on days when they were able to make an observation. Data to be recorded consisted of a drawing that showed the shape of the moon and its tilt, or orientation, relative to the horizon; the time of day or night the observation was made; the angle, when it could be determined, between the moon, Earth, and sun based on an approximation using numbers of fists; and the direction in which the students looked to see the moon. If a student looked and could not see the moon when the sky was clear, that fact also was recorded. At the beginning of each class, which met three times a week, a few students were asked to share a recent moon observation by placing their drawing and related data on the board. However, on some days, no drawings were available to be shared. When data were shared, a brief discussion followed, which sometimes included attention to similarities and differences in data shared by two or more individuals. Students sometimes reported having looked on several occasions during a clear day and evening without seeing the moon. For the days when they personally had not made an observation, students frequently added data shared by others into their charts. Sharing and discussion sessions averaged about 10 min in length, totaling about 3 h of class time over 9 weeks. These sharing sessions over 9 weeks were followed with about 5 h of intensive analysis of the data, including moving Earth, sun, and moon models in ways that could explain the data, and testing conjectures on the cause of moon phases. Early in the analysis, the small groups of students examined their moon chart data for variations and patterns, first within a day and, then, for longer periods. From this analysis, students concluded that a cyclical pattern of change in the observed moon phases was completed every 29–30 days, and any particular moon phase could be seen again after 29.5 days had elapsed. At

this point, synodic period and the names commonly used to describe various phases students had observed were introduced. Then the small groups arranged the eight named phases in the sequence they had observed. The terms *waxing* and *waning* were introduced, explained, and applied to the changing pattern of moon phases during a monthly cycle.

At this point in the analysis, attention was shifted to the pattern of change in the angle made by the moon, Earth, and sun and how changes in the angle are related to changes in moon phases. Using a white Styrofoam sphere as a prop, the small groups were asked to think about and write an explanation or description of a mental model of why the moon appears as it does and why it varies in appearance over time.

After discussions of proposed explanations occurred in small groups, each student took the Styrofoam sphere into a room that was darkened, except for a single illuminated incandescent bulb. With the guidance of an instructor each student began to move the sphere, which was held with arm extended, around his or her head, attempting to replicate the observed moon phases and patterns of change. The light bulb represented the sun, the student's head the Earth, and the Styrofoam sphere the moon. Students concluded that the moon revolves counterclockwise around the Earth in producing the moon phases in the order they had observed. Each student then reworked a written explanation for the cause of moon phases, including how the moon revolves around the Earth, how much of the moon is illuminated, and how much of the illuminated portion is visible from Earth. In response to a popular view that the phases of the moon are caused by the Earth's shadow, the small groups discussed this explanation and engaged in further modeling to test it. They concluded that a shadow model was not consistent with the observations they had made and rejected this idea as a plausible explanation for the cause of moon phases.

In summary, this inquiry-oriented instruction involved the preservice teachers in making systematic observations over an extended period of time and engaged them in sense making, interpretive discussions of their own observations. This constructivist design encouraged participants to maintain a high degree of awareness of their own thinking and understanding as they mentally processed a steady inflow of observations and made conjectures. Instruction with these characteristics has good potential to facilitate intentional learning (Bereiter & Scardamalia, 1989; Hennessey, 2003), thought to be crucial for deep conceptual understanding.

The total amount of in-class instructional time devoted to a study of moon phases was approximately 8 h, or 10% of the class time available for the course during one semester. Previous research (Trundle et al., 2002) has shown that this same instruction was very effective in helping preservice elementary teachers construct a scientific understanding of the cause of moon phases. Whether or not, with no additional effort, the instruction also positively impacts knowledge of observable moon phases and the pattern of change in the phases is revealed in the sections of the paper that follow.

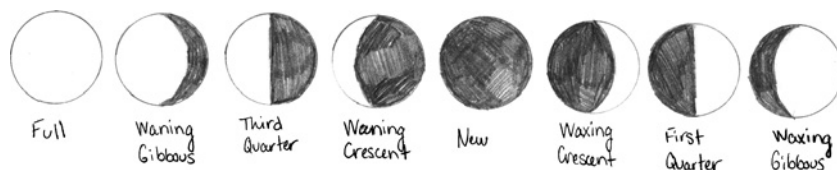


Figure 1. *Drawing showing scientific moon shapes and scientific waning and waxing sequences.*

Data Analysis

Initially, all three members of the research team independently analyzed and coded the participants' drawings, using a coding sheet based on previous research (Trundle et al., 2002). The coding sheet facilitated analysis of responses for Tasks 1 and 3 and helped standardize coding among researchers (Coffey & Atkinson, 1996). Participants' drawings were coded as reflecting knowledge consistent with a scientific understanding or knowledge consistent with a nonscientific, or alternative, conception (Hewson & Hewson, 1983). (See Figure 1 for an example of a drawing with scientific moon shapes and scientific waning and waxing sequences.) The team met periodically to calibrate analyses and to ensure interrater agreement. The three researchers' initial interrater agreement was 92.3% for the preinstruction sets of drawings and 96.1% for the postinstruction sets of drawings, resulting in 94.2% coding agreement on all sets of drawings combined. When a discrepancy arose among individual analyses, the team members reviewed the drawings together, discussed discrepancies in coding, and reached consensus on the categorization.

Results and Discussion

Results of analyzing and coding the drawings are summarized in Table 2. On the preassessment, only a modest number of participants made attempts to draw most of the eight commonly named phases. In fact, less than half of the sample indicated on Task 1 that they expected to observe a waxing gibbous, waxing crescent, first quarter, or waning gibbous. Note that the participants were not asked to name or label the phases. Rather, they simply were asked to draw the phases they expected to observe. The preinstruction results for the drawing component of Task 3 reveal only minor differences from Task 1. For both Tasks 1 and 3, the difference in the number of people who completed waning and waxing phase drawings is striking. Specifically, there were 104 instances where participants drew waning phases compared to 58 instances of drawing waxing phases. It seems unlikely that either casual observations of the moon over many years—or instruction in school—would lead to so much more awareness of waning phases. The important influence of social and cultural factors has been implicated in other studies of conceptual understanding (Vosniadou, 1994), and social and cultural influences are proposed as an explanation in this case. For example the authors have noted that advertisements in newspapers for “midnight

Table 2*Frequencies of Participants Who Included Specific Moon Phases in Drawings*

Moon phases	Task 1 (<i>N</i> = 52)				Task 3 (<i>N</i> = 52)			
	Pre		Post		Pre		Post	
	Sci	Non-Sci	Sci	Non-Sci	Sci	Non-Sci	Sci	Non-Sci
Full	51	1	51	1	51	0	51	1
Waning gibbous	11	14	50	0	13	15	50	0
Third quarter	29	9	51	0	30	4	51	0
Waning crescent	37	4	51	1	33	8	51	1
New	18	0	51	1	18	0	51	1
Waxing crescent	21	3	50	1	20	6	50	1
First quarter	17	4	50	0	18	2	50	0
Waxing gibbous	7	6	50	1	6	6	50	1
All drawings	19	33	48	4	23	29	48	4

madness” sales usually include a waning moon shape drawing, and it’s most often a waning crescent. Further, local newspapers frequently use a moon shape as a graphic to support a prediction of a clear to mostly clear night ahead. The shape consistently used in the local newspaper of two of the authors is a waning crescent.

Drawing a nonobservable or nonscientific shape is judged to reflect a greater deficiency than simply omitting an observable shape. The extent to which subjects who omitted observable phases could have drawn them, if but for a memory lapse, is unknown. Information to complete the full moon drawing was essentially given with the instructions for Tasks 1 and 3, although one person didn’t accept the gift. Excluding the new and full moon, in 40 of 162 cases for Task 1 and 41 of 161 cases for Task 3, nonscientific phases were drawn. The nonscientific waxing and waning crescent phases were drawn either as over- or underarticulating. More troubling, nonscientific first and third quarter moons were drawn like a curved “half moon,” consistent with a partial lunar eclipse. Again, the media are prime suspects as contributors to this troubling result. The local newspaper of two of the investigators daily uses graphics and dates to indicate when a full moon, new moon, first quarter and third quarter will occur, showing how these phases will look. The graphics for the quarters depict a curved half moon consistent with a partial lunar eclipse.

The most negative pretest results were obtained for the gibbous drawings. For Tasks 1 and 3 combined, only 24 of the 53 participants who drew waning gibbous drawings drew observable, scientific phases. Only 13 of the 25 participants who drew waxing gibbous drawings drew scientific phases. All of the nonscientific drawings were consistent with the understanding of moon phases being caused by the Earth’s shadow, which only can be observed during a lunar eclipse. We called these nonscientific shapes that were consistent with an eclipse and showed more

Table 3

Frequencies of Participants Who Included Scientific and Nonscientific Sequencing of Preinstruction and Postinstruction Drawings of Moon Phases

Sequence	Pre (<i>N</i> = 52)		Post (<i>N</i> = 52)	
	Sci	Non-Sci	Sci	Non-Sci
Moon wanes	14	25	40	12
Moon waxes	9	25	43	9
Moon wanes and waxes	2	50	39	13

than a quarter moon but less than a full moon a “false gibbous.” The frequency of false gibbous drawings, plus the frequency with which gibbous drawings were omitted, collectively represents a major deficiency in many preservice teachers’ content knowledge requiring attention.

Findings from the present study are in agreement with previous research on the cause of moon phases in that all of the studies have consistently reported a significant segment of the population, including preservice teachers, mistakenly believes that the moon’s phases are caused by the Earth’s shadow (Callison & Wright, 1993; Cohen, 1982; Dai & Capie, 1990; Kuethe, 1963; Sadler, 1987; Schoon, 1992, 1995; Stahly et al., 1999; Trundle et al., 2002; Zeilik et al., 1999).

Pretest results for Task 2 revealed that all 52 preservice teachers responded affirmatively to the question of whether they expected the moon phases to appear in a predictable sequence. However, as shown in Table 3 only 14 of the 39 persons (35.9%) who attempted to draw the waning moon phases in the sequence they expected to observe were judged to consistently use a scientific representation. The result was even poorer for a waxing sequence with only 9 of 34 (26.5%) attempts being classified as scientific. Note that all waxing and waning phases listed in Table 2 did not have to be included in order for a sequence drawn by a participant to be classified as scientific. Rather, only enough drawings had to be included to show the waxing or waning phenomena.

The errors made in sequencing phases were quite varied, with no single error being shown by a majority. A few persons sequenced first and third quarter phases, waxing and waning crescents, or waxing and waning gibbous drawings side by side. Waning phases also were mixed in with waxing phases in other ways, as were waxing phases with waning phases.

Some overall results merit highlighting. The “All drawings” row of Table 2 reveals that, before instruction, most participants included alternative, nonscientific phases in their moon drawings (33 of 52, 63.4%), while 19 participants (36.6%) drew only scientific moon phases. From Table 3, before instruction, most participants’ knowledge of the regularly recurring pattern of moon phases (50 of 52, 96.2%) was described as nonscientific, and only 2 participants (3.8%) drew both waning and waxing scientific moon phase sequences. Not revealed in the tables is the finding

that just one person (1.9%) was able to draw all eight commonly taught scientific phases and draw them in waxing and waning sequences.

Collectively the pretest results indicate this group of preservice elementary teachers was not prepared to lead K–4 students in documenting the observable moon phases and the recurring waxing and waning pattern of change in the phases, as required in the National Science Education Standards. Fortunately, the posttest results that follow indicate the pretest condition is largely treatable.

An examination of post test results in Table 2 reveals that at least 50 of the 52 participants attempted to draw each of the expected phases in response to Tasks 1 and 3. Further, for each phase, 50 or 51 participants recorded scientific drawings, while no more than 1 person drew a nonscientific drawing for any phase. That's about as good as it gets. The five nonscientific drawings of phases provided in response to Task 1 and again for Task 3 were drawn by 4 different participants. Hence, 48 of 52 (92.3%) participants drew all of the shapes correctly.

Postinstruction responses to Task 3, which required moon phase representations to be placed in the proper waxing and waning sequences, are summarized in Table 3. These results reveal major improvements in performance when compared to preinstruction results. First, all 52 participants attempted to draw both a waxing and waning sequence. Further, 40 (76.9%) participants' waning sequences were classified as scientific, and 43 (82.7%) of the 52 participants' waxing sequences were judged to be scientific representations. Of the 13 different participants who presented alternative representations of either a waning or waxing moon sequence, or both, 4 included waxing moon phases in a waning sequence and waning phases in a waxing sequence, while preserving the proper increase or decrease in the size of the observable shapes in the sequence. This type of deficiency is cause for concern, but not as much as the inclusion of a nonobserved alternative phase, such as a false gibbous (nonscientific shapes that were consistent with an eclipse). Only 1 person drew a false gibbous after instruction. Four participants drew a scientific waxing sequence along with a waning sequence that included some waning phases in the wrong order. Only 4 participants drew eight phases with no discernable sequence. Three of 13 participants who had difficulty sequencing the phases for Task 3 exhibited other problems in their postinstruction drawings, such as omitted phases.

Posttest results and gains from the pretest are summarized in Table 4, which combines results for both phases and sequences. After instruction, 92.3% of participants drew scientific moon phases, compared to 36.6% preinstruction. Further, after instruction, most participants drew scientific moon phase sequences (75%) compared to only 3.8% prior to instruction. Most participants were able to draw both scientific moon phases and sequences (69.2%) after instruction. The gains from preinstruction to postinstruction are notable. Postinstruction results indicate that learning to draw the observable phases in the proper waxing and waning sequences is more conceptually challenging than merely learning to draw the observable phases.

To support the qualitative comparisons, a nonparametric statistical test was used to examine the numbers of participants who shifted in content knowledge

Table 4*Gains From Pretest to Posttest*

Participant's drawings consisted of	Pretest ($N = 52$)	Posttest ($N = 52$)	Gain (posttest-pretest)
Scientific moon phases	36.6%	92.3%	55.7 percentage points
Scientific waning and waxing sequences	3.8%	75.0%	71.2 percentage points
Scientific phases and sequences	1.9%	69.2%	67.3 percentage points

from alternative or scientific drawings from pre- to the posttest. The Wilcoxon Signed Ranks Test examined the paired dichotomous categories for all possible shifts in accuracy (e.g., drawing alternative moon shapes on the pretest and shifting to scientific shapes on the posttest or drawing alternative moon shapes on both the pretest and posttest with no shift). Significantly more preservice teachers shifted from drawing alternative shapes on the pretest to drawing scientific shapes on the posttest than any other possibility ($Z = 5.209$, $p < .001$). Results for the sequences were similar in that significantly more participants shifted from drawing alternative waxing and waning sequences on the pretest to drawing scientific sequences on the posttest ($Z = 6.083$, $p < .001$). Also, significantly more preservice teachers shifted from drawing both alternative shapes and sequences on the pretest to drawing both scientific shapes and sequences after instruction ($Z = 5.916$, $p < .001$).

The level of cognition in which students engage in learning to draw scientific moon phases and sequences is a matter worthy of discussion. Clearly a student simply could have memorized the shapes and sequences and accurately recalled them on the postassessment. However, recall is not always simple. On some instructional days when two students shared moon observations that had been made independently within an hour or two of each other, the shapes drawn were strikingly different. Although students had been told to make a sketch at the time of the observation or shortly after, students argued that it was not always convenient to do so. Occasionally the drawings were nonscientific, being over- or underarticulated or even reflecting an eclipse model. When challenged by classmates, these students would argue strongly that they had just drawn what they had observed. However, if, at the urging of the instructor, they were able to make a sketch at a second observation about 24 h from the first, they sheepishly admitted the first sketch could not have been an accurate representation. The drawing of nonscientific moon shapes made after direct observations could have been influenced by nonscientific explanatory frameworks that the students held. Further, the large number of nonscientific drawings of phases and sequences made on the preassessment seems more likely to reflect nonscientific explanatory frameworks than faulty memories. It seems more probable that cultural influences, especially the popular media (Vosniadou, 1994), were contributors to the development of nonscientific frameworks than prior instruction. The instruction provided in this investigation encouraged students

to compare alternative explanatory frameworks. It did not include drill and practice exercises to promote the memorization of scientific shapes and sequences or provide an authoritative explanation to be memorized.

Conclusions and Implications

Based on the preinstruction results, we conclude that neither any previous study of the moon that may have occurred in school nor years of being generally aware of the moon outside of school was effective in helping these preservice teachers learn to draw observable moon phases and the recurring pattern of change in observable phases. Considering the greater frequency with which waning phases were drawn, compared to waxing phases, nonscientific “eclipse” drawings were included, and the extent to which these drawings seem to be favored by the popular media, we speculate that cultural factors were more influential on participants’ learning than schooling or personal observations of the moon. Again, the importance of popular culture in conceptual understanding has been well documented. For example, see Vosniadou (1994) and Vosniadou and Brewer (1992). Collectively the preinstruction results are consistent with responses expected from persons with fragments of knowledge (diSessa, 1988) about the moon, but who lack a coherent scientific explanatory framework for observable moon phenomena. In any case, preinstruction results clearly indicate these preservice elementary teachers were not prepared to lead K–4 students in addressing standards-based moon content. The extent to which other groups of preservice elementary teachers would show the same conceptual difficulties is unknown, but it seems likely that this is a broadly shared problem in science teacher education, rather than an isolated case.

The good news for scientists and science educators who wish to address the problem is that the instructional intervention that proved to be highly effective in the present study can easily be implemented in other teacher preparation programs. Further, the instruction simultaneously provides a major bonus in that most preservice elementary teachers who completed the instruction were able to demonstrate a scientific understanding of the cause of moon phases (Trundle et al., 2002). For those of us who believe teachers’ knowledge should extend beyond what they are expected to teach children, that is impressive. After instruction, almost all participants were able to draw scientific representations of the eight moon phases commonly included in instruction. Approximately four of five persons were able to make and place scientific drawings of the phases in the proper waxing and waning sequences. Results suggest instruction could perhaps be improved if the small groups focused more attention on the critical attributes that distinguish waxing from waning crescents, first from third quarters, and waxing from waning gibbous moon phases. This addition, which could be made late in the instructional sequence, would be an attempt to address the most common knowledge deficiencies that persisted after instruction. However, any modification of the instruction should maintain the inquiry nature of the activities and sense-making discussions, which are more likely to promote desirable intentional learning (Bereiter & Scardamalia, 1989; Bransford,

Franks, Vye, & Sherwood, 1989; Vosniadou, 2003) than more traditional, didactic approaches.

Describing what teachers know about standards-based lunar concepts and identifying instruction that helps teachers improve their content knowledge are important steps in eventually improving classroom instruction for elementary children. Future research should build on this foundation and investigate how teacher knowledge impacts instructional effectiveness for this standards-based topic.

References

- Abell, S., George, M., & Martini, M. (2002). The moon investigations: Instructional strategies for elementary science methods. *Journal of Science Teacher Education, 13*, 85–100.
- Barnett, M., & Morran, J. (2002). Addressing children's alternative frameworks of the moon's phases and eclipses. *International Journal of Science Education, 24*, 859–879.
- Baxter, J. (1989). Children's understanding of familiar astronomical events. *International Journal of Science Education, 11*, 502–513.
- Bereiter, C., & Scardamalia, M. (1989). Intentional learning as a goal of instruction. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 361–392). Hillsdale, NJ: Erlbaum.
- Bisard, W. J., Aron, R. H., Francek, M. A., & Nelson, B. D. (1994). Assessing selected physical science and earth science misconceptions of middle school through university preservice teachers. *Journal of College Science Teaching, 24*, 38–42.
- Bransford, J. D., Franks, J. J., Vye, N. J., & Sherwood, P. D. (1989). New approaches to instruction: Because wisdom can't be told. In S. Vosniadou & A. Ortony (Eds.), *Similarity and analogical reasoning* (pp. 470–497). New York: Cambridge University Press.
- Callison, P. L., & Wright, E. L. (1993, April). *The effect of teaching strategies using models on preservice elementary teachers' conceptions about earth-sun-moon relationships*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Atlanta, GA.
- Coates, E. (2002). "I forgot the sky!" Children's stories contained within their drawings. *International Journal of Early Years Education, 10*(1), 21–35.
- Coffey, A., & Atkinson, P. (1996). *Making sense of qualitative data: Complementary research strategies*. Thousand Oaks, CA: Sage.
- Cohen, M. R. (1982). *How can sunlight hit the moon if we are in the dark?: Teacher's conceptions of phases of the moon*. Paper presented at the 7th annual Henry Lester Smith Conference on Education Research, Bloomington, Indiana.
- Cohen, M. R., & Kagan, M. H. (1979). Where does the old moon go? *The Science Teacher, 46*, 22–23.
- Cuthbert, A. J. (2000). Do children have a holistic view of their internal body maps? *School Science Review, 82*(299), 25–32.

- Dai, M., & Capie, W. (1990, April). *Misconceptions held by the preservice teachers in Taiwan*. Paper presented at the annual meeting of the National Association of Research in Science Teaching, Atlanta, GA.
- diSessa, A. A. (1988). Knowledge in pieces. In G. Forman & P. Pufall (Eds.), *Constructivism in the computer age* (pp. 49–70). Mahwah, NJ: Erlbaum.
- Dove, J. E., Everett, L. A., & Preece, P. F. W. (1999). Exploring a hydrologic concept through children's drawings. *International Journal of Science Education*, 21, 485–497.
- Edens, K. M., & Potter, E. (2003). Using descriptive drawings as a conceptual change strategy in elementary science. *School Science and Mathematics*, 103, 135–144.
- Glesne, C., & Peshkin, A. (1992). *Becoming qualitative researchers: An introduction*. White Plains, NY: Longman.
- Golomb, C. (1992). *The child's creation of a pictorial world*. Berkeley: University of California Press.
- Haupt, G. W. (1950). First grade concepts of the moon. *Science Education*, 34, 224–234.
- Hayes, D., Symington, D., & Martin, M. (1994). Drawing during science activity in the primary school. *International Journal of Science Education*, 16, 265–277.
- Hewson, M. G., & Hewson, P. W. (1983). Effect of instruction using students' prior knowledge and conceptual change strategies on science learning. *Journal of Research in Science Teaching*, 20, 731–743.
- Hennessey, M. G. (2003). Metacognitive aspects of students' reflective discourse: Implications for intentional conceptual change teaching and learning. In G. Sinatra & P. Pintrich (Eds.), *Intentional conceptual change* (pp. 103–132). Mahwah, NJ: Erlbaum.
- Jones, B. L., & Lynch, P. P. (1987). Children's conceptions of the earth, sun, and moon. *International Journal of Science Education*, 9(1), 43–53.
- Kueth, J. L. (1963). Science concepts: A study of "sophisticated" errors. *Science Education*, 47, 361–364.
- Mason, J. (1996). *Qualitative researching*. Thousand Oaks, CA: SAGE.
- McDermott, L. (1996). *Physics by inquiry*. New York: John Wiley & Sons.
- Moline, S. (1995). *I see what you mean: Children at work with visual information*. York, ME: Stenhouse Publishers.
- National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.
- Rennie, L. J., & Jarvis, T. (1995). Children's choice of drawings to communicate their ideas about technology. *Research in Science Education*, 25, 239–252.
- Rubin, H. J., & Rubin, I. S. (1995). *Qualitative interviewing: The art of hearing data*. Thousand Oaks, CA: SAGE.
- Sadler, P. M. (1987). Misconceptions in astronomy. In *Proceedings of the Second International Seminar on Misconceptions and Educational Strategies in Science and Mathematics* (pp. 422–425). Ithaca, NY: Cornell University.
- Schoon, K. J. (1992). Students' alternative conceptions of earth and space. *Journal of Geological Education*, 40, 209–214.

- Schoon, K. J. (1995). The origin and extent of alternative conceptions in the earth and space sciences: A survey of pre-service elementary teachers. *Journal of Elementary Science Education*, 7(2), 27–46.
- Stahly, L. L., Krockover, G. H., & Shepardson, D. P. (1999). Third grade students' ideas about lunar phases. *Journal of Research in Science Teaching*, 36, 159–177.
- Strommen, E. (1995). Lions and tigers and bears, oh my! Children's conceptions of forests and their inhabitants. *Journal of Research in Science Teaching*, 32, 683–698.
- Targan, D. (1988). *The assimilation and accommodation of concepts in astronomy*. Unpublished doctoral dissertation, The University of Minnesota, Minneapolis.
- Treagust, D. F. (1988). Development and use of diagnostic tests to evaluate students' misconceptions in science. *International Journal of Science Education*, 10, 159–169.
- Trundle, K. C., Atwood, R. K., & Christopher, J. E. (2002). Preservice elementary teachers' conceptions of moon phases before and after instruction. *Journal of Research in Science Teaching*, 39, 633–658.
- Van Meter, P. (2001). Drawing construction as a strategy for learning from text. *Journal of Educational Psychology*, 93, 129–140.
- Vosniadou, S. (1994). Universal and culture specific properties of children's models of the earth. In L. A. Hirschfield & S. A. Gelman (Eds.), *Mapping the mind* (pp. 412–430). New York: Cambridge University Press.
- Vosniadou, S. (2003). Exploring the relationship between conceptual change and intentional learning. In G. Sinatra & P. Pintrich (Eds.), *Intentional conceptual change* (pp. 377–406). Mahwah, NJ: Erlbaum.
- Vosnaidou, S., & Brewer, W. F. (1992). Mental models of the Earth: A study of conceptual change in childhood. *Cognitive Psychology*, 24, 535–585.
- White, R., & Gunstone, R. (1992). *Probing understanding*. London: Falmer Press.
- Zeilik, M., Schau, C., & Mattern, N. (1999). Conceptual astronomy: Replicating conceptual gains, probing attitude changes across three semesters. *American Journal of Physics*, 67, 923–927.