Third Grade Students' Ideas about the Lunar Phases

Laura L. Stahly,[1] Gerald H. Krockover,[2] Daniel P. Shepardson[2]

[1]*Tigard Elementary School, Tigard, Oregon 97224*

[2]*School Mathematics and Science Center, 1442 Liberal Arts and Education Bldg., Purdue University, West Lafayette, Indiana 47907-1442*

Received 25 January 1997; revised 12 January 1998; accepted 17 March 1998

Abstract: The purpose of this study was to examine third-grade students' ideas about the lunar phases prior to and following an instructional period designed to promote students' conceptual change. Four third-grade students enrolled in an elementary school near a large midwestern university participated in this study. Qualitative methods of interviewing and observation were used to identify students' conceptions of the lunar phases. Analytical induction was used to analyze data collected in the forms of researcher notes and transcriptions of audio- and videotaped interviews and lessons. The results of this study indicated that students held individual views that were scientifically accurate; however, they also held conceptions that were scientifically inaccurate. In addition, the results demonstrate that students are capable of making conceptual changes; however, they also continued to hold views that were inconsistent with the scientific perspective. © 1999 John Wiley & Sons, Inc. J Res Sci Teach 36: 159–177, 1999

A report from the National Center for Improving Science Education (1989) indicates that "only a small percentage of the students who pass through schools develop any useful scientific understanding. The educational system may be continuing to produce enough highly trained engineers and scientists, but most Americans appear to lack even a basic understanding of science and technology" (p. 1). Consequently, research involving children's understanding of scientific concepts has become more prevalent within educational communities. One aspect of the research involves identifying the alternative conceptions that exist among students at various ages. To investigate the implications of children's alternative concepts, one must have an understanding of how they develop their ideas and belief systems. Constructivist theory posits that learners develop ideas and beliefs about the world before they receive formal instruction (Ault, 1984; Baxter, 1989; Driver & Oldam, 1986; Kuethe, 1963; Mali & Howe, 1979; Nussbaum & Novak, 1976; Schoon, 1992; Stronimen, 1995). These ideas and beliefs; both new and old, are synthesized into cognitive structures which reflect the organization of their understanding based upon personal experiences (Saunders, 1992). Constructivism also views learning as a social process of making sense of experiences in terms of what is already known (Driver & Oldham, 1986; Tobin & Tippins, 1993; Wittrock, 1974). From this perspective, knowledge occurs as a

Correspondence to: G.H. Krockover

 CCC 0022-4308/99/020159-19

result of constructive activity; therefore, it cannot be transferred in a passive way (von Glasersfeld, 1993). When people experience the same situation and information, they each construct divergent conceptions owing to their varied prior experiences and existing knowledge (Hewson, 1991).

Children experience the lunar phases in formal and informal learning situations many times throughout their lives. Each time, they use their existing cognitive frameworks to give meaning to the experience. When children encounter new experiences or stimuli, the new information may be integrated into their existing framework; or the conceptions, both new and old, could be reorganized; or the currently held conceptions could be rejected. In these ways, children create individualized cognitive structures based upon their prior and current experiences with the lunar phases. As a result, children may create conceptions that are counter to the scientifically accepted view.

Philips (1991), in a review of the research literature, detected that children held alternative conceptions for the lunar phases. Furthermore, he compiled a list of what he called common misconceptions that occur across all age groups. Alternative conceptions for the lunar phases with students in Grades 5–9 were detected in his review of the research literature. Bisard et al.'s (1994) findings extended the ages to include high school and college students. Both found that participants selected an alternative conception as the correct answer on the question regarding the cause of lunar phases. Additional studies (Baxter, 1989; Callison & Wright, 1993; Kuethe, 1963; Dai & Capie, 1990) identified similar alternative conceptions for the lunar phases. In addition, Baxter (1989) identified five frequently occurring notions featured by children aged 9–16 regarding the phases of the moon:

1. Clouds cover the part of the moon that we cannot see.
2. Planets cast shadows on the part of the moon that we cannot see.
3. The shadow of the sun falls on the moon, blocking our view of it.
4. The shadow of the earth falls on the moon, blocking our view.
5. The phases are explained in terms of the portion of illuminated side of the moon visible from the earth (scientific viewpoint).

Although the various alternative conceptions exist, the most commonly held notion for the causes of lunar phases is that the earth casts a shadow on the moon: the eclipse explanation. Kuethe (1963) found that 70% of his male subjects used this eclipse explanation for the phases. Using a multiple choice instrument, Schoon (1992) found that the eclipse explanation was selected by 48% of his participants. Two additional studies (Bisard et al., 1994; Sadler, 1987) found that 38% and 37% of their participants respectively agreed with the eclipse explanation. Studies involving preservice teachers also found that the eclipse notion was the most frequently given response for the cause of the lunar phase (Callison & Wright, 1993; Dai & Capie, 1990; Schoon, 1995).

The *National Science Education Standards* (National Research Council, 1996) assert that "By Grades five through eight, students have a clear notion about gravity, the shape of the earth, and the relative positions of the earth, sun, and moon. Nevertheless, more than half of the students will not be able to use these models to explain the phases of the moon" (p. 159). This statement acknowledges the complexity of the lunar phase phenomena and identifies it as challenging for students in Grades 5–8. Similarly, *Benchmarks for science literacy* (AAAS, 1993) asserted that the lunar phase phenomena is a complex concept to learn. "The benchmarks here call for students to be able to explain two phenomena—the seasons and the phases of the moon—that are usually not learned well. Most adults are unable to give even approximately correct explanations for them. Most students are told by teachers what causes the seasons and the phases of the moon, and they read about them without understanding. Moon phases are difficult because of students' unfamiliarity with the geometry of light and 'seeing.' To help figure out the geometry, students can act out the sun–earth–moon relationships and make physical models" (AAAS, p. 66). The benchmark for lunar phases is not introduced until Grades 6–8.

Purpose of Study

Much of the prior research on children's conceptions about the lunar phases consisted of surveys or multiple choice instruments (Baxter, 1989; Dai & Capie, 1990; and Kuethe, 1963). These methods only allowed participants to choose responses from those that were featured on the instrument. It is possible that the participants could have had alternative ideas which were not represented on the survey. Therefore, this study features a qualitative approach to discover and interpret children's ideas about the lunar phases. In this way, children were able to provide their own ideas and explanations rather than selecting one from a list of potential answers. Furthermore, the concept of lunar phases is introduced at the third-grade level; thus, it is essential to investigate third graders' understandings of the lunar phases. In this way, children's existing alternative conceptions could be identified and science educators could use this information to create or modify instruction that better meets the needs of learners.

The following research questions guided this study and the analysis and interpretation of the students' responses.

1. What are third-grade students' conceptions of the lunar phases and why the lunar phases occur?
2. In what ways are the third-grade students' ideas consistent or inconsistent with the scientifically accepted perspective?
3. Do third-grade students' conceptions of the lunar phases change after participating in activities featuring the scientific view? If so, in what ways? If not, in what ways do they remain the same?

Methodology

A qualitative method was selected for this study to investigate the nature of students' ideas about lunar phases. The point of the inquiry method was to understand naturally occurring phenomena in their naturally occurring state (Patton, 1990). Through the use of qualitative methods, in-depth, detailed data which captured the participants' personal perspectives could be collected without constraining them to predetermined categories or anticipated responses.

Constructivism asserts that people do not merely discover knowledge, but that they construct or make it. People invent concepts, models, and schemes to make sense of experience. In addition, these constructions are continually modified and refined as new phenomena are experienced (Schwandt, 1994). This study was conducted from a constructivist framework in that students constructed meanings of the lunar phases prior to instruction and they constructed meaning during and following instruction. As researchers, we constructed our understanding and interpretation of the students' ideas; therefore, we used an interpretivist framework as well. Consequently, two levels of conceptual construction occurred in this study. The first level involved the students constructing or refining their conceptions of the lunar phases throughout the course of the study. The second level consisted of our attempts to interpret and gain a better sense of the students' conceptions through the various sources of data.

Setting and Participants

This study was conducted in a third-grade classroom at an elementary school in a midwestern city located near a major university. There were 12 boys and 9 girls, 8–9 years of age, in the class. Four of the 21 students were selected as key informants.

These students were selected, based on teacher recommendations, academic ability, gender, and verbal ability, to reflect the composition of the class. Furthermore, the review of research literature featured few previous studies which focused on the scientific and alternative conceptions of primary grade students. Second, the classroom teacher, Mrs. Coban, demonstrated an interest in this research project. She willingly opened her classroom so that we could further investigate the students' ideas. Third, the concepts of the lunar phases were components of the science curriculum for this class. It was also featured in the school's adopted science textbook.

Role of the Researcher

For this study, one of us assumed a dual role of researcher and teacher responsible for facilitating student learning of the lunar phases. Thus, as researcher/teacher, the role was to facilitate the instruction while also making observations regarding the students' actions. There was little time to record observations during the instruction. However, after each session the students' behavior and researcher/teacher perceptions regarding how the instructional phase was carried out were recorded. The teacher/researcher also participated as an interviewer prior to and following instruction to gain a better sense of the students' conceptions of the lunar phases. This role as an interviewer allowed the students' perspective to be included (Patton, 1990). As the four key informants were interviewed, the teacher/researcher listened, interpreted, and developed probing questions to further clarify understanding of their verbally expressed ideas. These roles allowed the teacher/researcher to further explore the students' constructed ideas regarding the lunar phases.

Methods

Data Collection Methods

Mrs. Coban and the teacher/researcher selected the four individuals who were representative of the school population. We considered the students' standardized test scores in the areas of mathematics, science, problem solving, and logical reasoning in addition to grades achieved in science during the second and third grades. These informational sources allowed students with different learning abilities to be selected. Of these 4 children, 2 were boys and 2 were girls. One of the key informants was a high-ability student, two were average-ability students, and the fourth was a low-ability student. In addition, the selections were based on Mrs. Coban's perception of the students' willingness to talk with the teacher/researcher. During the interviews, three of the key informants were open to questions and seemed to share their ideas freely. One of the key informants was very quiet during the interview and frequently did not respond to questions.

Additional conversations with Mrs. Coban took place during the instructional phase of the study. These conversations allowed Mrs. Coban to provide feedback regarding her perceptions of the students' responses to the various activities and the instructional methods that were featured. For instance, the use of cooperative groups and the various groupings that might present personality conflicts were discussed. Consequently, group assignments were made to reflect Mrs. Coban's awareness of personality conflicts. In addition, we talked about our perceptions regarding the students' reaction to the three-dimensional models of the sun–earth–moon system. The discussion allowed the day's instruction to be evaluated and the next instructional day's lesson to be adjusted. In this way, the feedback refined instruction to better meet the needs of the third-grade students.

A structured protocol was used to interview students' about their conceptions of the lunar phases. Two tasks were also used to elicit students' ideas about lunar phases. The students were asked to draw pictures for their explanation and create three-dimensional models to accompany their verbal responses. These interviews took place prior to the first lesson and after the final lesson, and provided information about the students' ideas regarding the lunar phases prior to and following the conceptual change activities. All of the students also completed a written survey regarding their conceptions of the lunar phases. The primary sources of data were the videotaped interviews and written surveys. The instructional handouts, videotaped classroom activities, and recorded observations served as secondary sources of data.

Data Analysis

The interview audiotapes were transcribed verbatim and analyzed through the process of analytic induction to find patterns in the students' responses to the activities and interview questions. To uncover these patterns, an iterative procedure was used. This entailed the continual examination and reexamination of the data to identify themes or patterns, which were then verified.

The analytical process involved extensive viewing of the videotapes and reading and rereading of the transcripts to gain a better sense of the students' conceptions of lunar phases. From the transcripts, an initial set of categories was generated. The initial categories were then reviewed and revised, with some of the student responses recategorized. The data were searched for discrepant cases in which student responses did not fit into the emergent themes. When discrepancies were detected, the cases were reanalyzed. If the discrepancy represented students' individual conceptions, a new category was created.

Next, student explanations were analyzed for consistency across the interview questions. In this way, potential discrepancies among responses to the interview questions were searched and found. In addition, students' three-dimensional models were analyzed for consistencies and discrepancy. This enabled us to identify whether similar patterns emerged from the various presentation forms: for instance, whether students' verbal responses corresponded with their drawings and constructed models. Students' responses on the written survey were also compared to those obtained during the interviews. This process was completed for each of the four key informants. Next, each key informant's conceptions were analyzed for similarities and differences. In this way, we were able to triangulate across data sources for each of the students. Finally, each student's conceptions were compared to the scientific perspective. This process was performed for the pre- and postinstructional data to compare the two sets of responses.

Instructional Context

Mrs. Coban's class had recently completed a science unit on the solar system; however, it did not discuss the lunar phases. The topic was featured in the classroom's science text in the chapter entitled "Sun, moon, and planets" (Mallinson et al., 1987). The first two lessons were presented on Monday and Friday. The third, fourth, and fifth lessons were featured the following week, on Monday, Thursday, and Friday. Finally, the fifth and sixth lessons were presented during the last week, on Monday and Thursday.

The purpose of the first lesson was to gain a better sense of the students' current conceptions about the lunar phases. Therefore, the lesson was designed to identify students' ideas and to provide an overview of the upcoming activities. Students worked individually, in small groups, and discussed ideas with the entire class. The second lesson provided students with activities with the sun as the moon's light source. In addition, the three-dimensional model of the sun, earth, and moon positioning for the full moon phase was introduced. The intention of these activities was to ensure that students were aware of the sun's role in the lunar phases.

The third day's lesson provided students with additional experiences investigating the three-dimensional model of the sun–earth–moon positions. In this way, the students observed what happened to the moon's shape as seen from earth when the moon's position changes in relation to the earth and sun. On the fourth day, students reviewed the group findings from their constructed three-dimensional models. After many scientifically inaccurate drawings were detected on the students' handouts from Day 3, a review of the previous day's lesson was conducted. The intention of this activity was to clarify the translation process of the two-dimensional drawings into three-dimensional models.

The fifth lesson further explored the sun–earth–moon positions and their matching lunar phases. The intention of these activities was to provide students with novel experiences highlighting a simulated occurrence of the lunar phases. In the first activity, students created images of the moon phases that would be observed with the given sun–earth–moon positions. In the second activity, the process was reversed: Students now had to create drawings of the sun–earth–moon positions to match the given moon phases. The intention was to give students a broader range of experience in moving from the moon phases to the sun–earth–moon positions, and vice versa. In this way, students experienced an additional model which simulated the lunar phases.

During the sixth lesson, students had additional experiences with the sun–earth–moon models to further explore the lunar phases. The intention of these activities was to familiarize the students with the process of determining the positions for the sun, earth, and moon based upon the given lunar phase. The purpose of the final lesson was to review the concepts of how lunar phases occur via the three-dimensional models. The activities served as a review of the process of determining the positions for the sun, earth, and moon for the given lunar phases.

Results

Synthesis of the Four Participants' Preinstructional Conceptions of the Lunar Phases

Two of the participants displayed similar notions for why we see different moon phases over time. Dale and Lois believed that it is one's vantage point on earth with relation to the moon that determines the shape that we see. The changing position of the X on the earth indicates that the earth rotates on its axis. Consequently, our perspective of the moon changes as we arrive at the different locations. Dales' comments and his three-dimensional models follow (Figure 1).

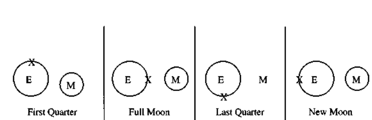

Figure 1. Dale's three-dimensional models for the lunar phases (the X indicates one's location on earth).

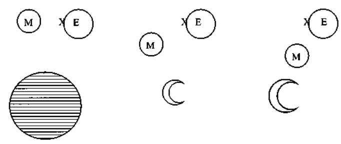

Figure 2. Lois' three-dimensional models corresponding to her drawings of the lunar phases.

I: How does it happen that we see the first quarter?
D: We get, like, sort of close. We don't get exactly facing the moon. We get a bit closer to the moon than what we were when there was a new moon. The same for the last quarter.

Lois' three dimensional models present her belief that it is one's perspective on earth relative to the moon which determines the lunar phases (Figure 2). According to her, it is the moon's revolution around the earth, not the earth's rotation on its axis, that creates the different lunar phases.

I: How does that happen?
L: Here's where America is [refers to a dot on the Styrofoam earth], and the moon's here, and when it goes, like . . . direct. [America facing the moon directly] The earth is or here's America [refers to the dot on the Styrofoam earth] directly at the moon, we see the whole moon.

None of the four students were concerned with the sun's role in the lunar phases, since they did not include it initially in their three-dimensional models. However, three of the participants indicated an awareness that the moon's light comes from the sun. The fourth student was unable to give a response when asked about the source of the moon's light. After the students were asked about the source of the moon's light, the three participants began to feature the sun in their models. However, it was not incorporated into their expectations for how the lunar phases occur. This indicates that perhaps they had memorized a fact about the moon from an earlier educational experience; however, they had not yet incorporated it into their explanation for the lunar phases, since they did not explain how the sun functions in the various arrangements of the earth and moon systems.

A third participant, Ann, asserted that the clouds create the phases of the moon in addition to what she called the earth's rotation. In other words, Ann labeled the earth's journey around the sun and moon "rotation" instead of the scientifically accepted term "revolution." However, the cloud coverage explanation takes precedence, since it occurred consistently in her three-dimensional models and drawings. Ann discussed the occurrence of the earth's path around the moon and the sun, but she included it only verbally and not when she constructed models or drawings. Cal, the fourth participant, did not provide an explanation for how we are able to see different shapes of the moon over time. Cal stated that the moon orbits the earth; however, he provided no clarification for his definition of "orbit" or how it allows us to see the lunar phases.

In conclusion, the written surveys, verbal responses, drawings, and three-dimensional models indicated that the students' understandings of the lunar phases were different from the scientific perspective. They created complex, somewhat consistent explanations which made sense according to their beliefs and observations. In addition, three of the participants seemed to experience some cognitive dissonance as they attempted to explain their ideas. Dale struggled with the occurrence of an eclipse and how it was different from the moon phases. He later incorporated the occurrence of an eclipse with his explanation by giving it the new moon label. Lois grappled with the earth's rotation and the occurrence of night and day in conjunction with the lunar phases. She appeared to have reconciled the phenomena; however, some inconsistencies still existed between her verbal responses and three-dimensional models. Finally, Ann debated with herself about whether the earth goes around the moon. Initially, she explained that the moon travels around the earth; however, she later gave up this idea when it occurred to her that the earth may orbit the moon. In this way, Ann's conceptions about the lunar phases were consistent for her.

Synthesis of the Four Participants' Postinstructional Conceptions of the Lunar Phases

All four participants displayed some similar notions regarding the cause of the lunar phases. Each student presented the view that the moon revolves around the earth, but each differed in the presentation manner. All of the key informants' three-dimensional models featured the moon in different positions around the earth.

This model is one example of how the students portrayed the movement of the moon during the interviews. Three of the key informants talked about the movement of the moon around the earth. However, the extent to which each student used scientific terminology varied across the three individuals.

> D: The moon moves around the earth and the sun reflects the light off the moon.
> L: The moon's a satellite of the earth; it goes around this way of the earth [indicates a revolution around a circle] . . . when it revolves around, it . . . shows different shapes in the sky.
> A: It's [the moon] going around the earth.

Dale's verbal comments illustrate how three of the students incorporated the factual information of the revolving moon into their cognitive frameworks. This does not necessarily imply, however, that the students' conceptions are complete with regards to the scientific explanation. In addition, Cal was very hesitant to share his ideas during the interview. It could be that he was aware of the revolving moon since it is featured in his constructed models, yet he did not feel comfortable verbalizing it.

All of the key informants displayed the revolving moon in their drawings. Dale, Lois, and Ann created drawings during the interview with the moon in different positions around the earth to explain how they believe we see different shapes of the moon. On the other hand, Cal's drawings on the written survey indicated that the moon revolves around the earth since it was featured in different locations in its orbit of the earth for two different phases of the moon.

Initially, it appeared that the students may have had ideas that were consistent with the scientific perspective. The moon does revolve around the earth, and the students seemed to be aware of this occurrence; however, the revolution of the moon is only part of the lunar phase phenomena. Therefore, further aspects must be considered when assessing the students' conceptions regarding the lunar phases.

All of the students included the sun's role in the creation of the moon phases; however, only three of the participants provided responses that indicated a more in-depth understanding. Cal

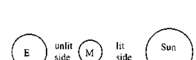

Figure 3. Dales' three-dimensional model for the new moon phase.

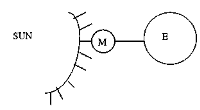

Figure 4. Lois' interview drawing of the new moon phase.

identified the sun as the moon's light source, but he did not offer clarification regarding how it relates to the moon phases.

I: Can you tell me about that one? [indicating the full moon]
C: It's all lit.
I: How is that when we're on earth, we see all of it?
C: By the sun. . . . The sun makes the moonlight lit.

Cal's comments represented his knowledge that the moon's light comes from the sun. However, they did not clarify whether Cal believed that the earth's position relative to the sun and moon also determines the shape of the moon. The other participants were aware that different portions of the moon received light from the sun depending on their relative positions to one another. These students also used three-dimensional models to support their verbal responses, as illustrated in Dale's comment and models (Figure 3).

D: The moon moves around the earth and the sun reflects the light off the moon and we see light. We can't see the light when it's like behind us [indicating that the sun reaches the side of the moon that faces away from earth].

Lois' drawing for the new moon phase indicated that she was aware that the sun's rays are only reaching one side of the moon (Figure 4). We cannot see the moon because the lit side faces away from earth during this phase. In addition, Ann's verbal comments and constructed three-dimensional models indicated an awareness that different sides of the moon receive light from the sun depending on their positions relative to one another (Figure 5).

A: Like, over here's the sun [refers to lamp] and then how the moon turns around [moves the Styrofoam moon around the Styrofoam earth] and it goes . . . and what we see from the . . . see the sun's not over here [indicates unlit side of the Styrofoam ball], it's right here [points to the lit side of the Styrofoam ball] so that makes a shadow.

Verbal comments, drawings, and constructed three-dimensional models indicated that three of the participants were aware that different portions of the moon receive light depending upon the relative positions of the sun and moon. However, it cannot be determined from these excerpts whether these students incorporated the role that the earth's position relative to the moon and sun plays in the lunar phases. Further examination of the students' verbal responses, drawings, written comments, and three-dimensional models clarify this point.

Three of the participants' verbal responses, drawings, and three-dimensional models indicated that one's perspective from earth contributes to the lunar phase process. Dale's initial com-

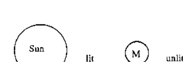

Figure 5. Ann's three-dimensional model for "shadows."

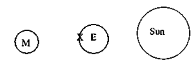

Figure 6. Dale's three-dimensional models for the new and full moon phase.

ments indicated more specifically that it is one's location on the earth that influences the phase that is experienced.

> D: . . . Where we are, Indiana, it's . . . it depends, so if it's [the moon], like, away from Indiana, you'll see a new moon [see Figure 3]. . . . If it's . . . right in front of us, we'll see a full moon [Figure 6].

Dale's constructed three-dimensional models included Indiana's location on the earth, and his verbal comments indicated that this position on the earth relative to the sun and moon influences the shape of the moon that is seen (Figure 6). Similarly, Lois' work with the three-dimensional models demonstrated an awareness that the earth's perspective of the moon determines what lunar phase is observed.

> L: Here's the sun [refers to lamp]. I'll use this as the moon [refers to smaller Styrofoam ball]. I think the moon goes around like that [moves the Styrofoam moon in a circle around the Styrofoam earth]. Then, if we're right there or where that circle is [indicating Indiana's location on the earth] . . . it keeps going around and, like, when it's right here, you see only half of it.

These comments featured the notion that one's specific location on the earth relative to the sun and moon determines what moon phase is observed. In addition, during the interview, Lois evaluated the accuracy of her drawings through the three-dimensional models and continually moved herself into a position that would allow her to view the moon from the earth's perspective. This indicated that Lois was aware that the earth's position relative to the sun and moon creates the given lunar phases.

Ann's verbal comments and some of her constructed three-dimensional models indicated an awareness of the earth's role in the lunar phase process. Her comments and model for the last quarter moon are consistent with the scientific view (Figure 7).

> A: From what we see from earth, it's, um . . . like there's a half moon right there [refers to the left side of the Styrofoam moon].

Ann gave a scientifically accurate description of the earth's perspective for the given sun–earth–moon positions. She featured the appropriate lit portion of the moon as viewed from the earth for this example.

Conversely, Cal's constructed three-dimensional models did not seem to take into consideration that one's perspective from the earth determines the observed moon shape. He featured a scientifically inaccurate match between the sun–earth–moon positions and the last quarter

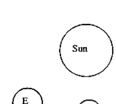

Figure 7. Ann's three-dimensional model for the half-moon phase.

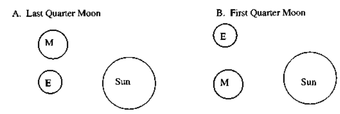

Figure 8. Cal's three-dimensional models for the last (A) and first (B) quarter moon phase.

(Figure 8A) and first quarter moon (Figure 8B). Cal's models indicated that he was not aware that one's perspective on the earth influences the moon's shape. He inaccurately linked the sun–earth–moon position with the given phase; therefore, it appeared that Cal did not incorporate the earth's perspective relative to the sun and moon as an important factor in the creation of the lunar phases. Interestingly, a similar phenomenon occurred for Dale and Ann, although for them it was demonstrated with the gibbous and crescent phases.

Dale displayed drawings for the gibbous and crescent moon phases that were inconsistent with the scientific perspective. Ann displayed the inconsistency only for the gibbous phase; however, in addition to featuring the inaccurate lit portion of the moon, she also featured an inaccurate lunar phase for the given sun–earth–moon positions. In other words, she drew a waxing crescent when the scientific perspective would feature a waning gibbous moon (Figure 9). These constructed models by Dale and Ann indicated an inconsistency with their previous drawings and statements regarding the role that the earth's position plays for the lunar phases. On the one hand, they displayed an awareness of the changing moon's shape due to the earth's position related to the sun and moon; however, they did not seem to apply it in these situations.

Discussion

It appears that the four key informants' conceptions changed from the pre- to the postinstructional assessment of their ideas. Each individual expressed a personalized conception regarding the lunar phases both prior to and following instruction. The students' preinstructional responses appeared to be less consistent with the scientifically accepted perspective and they did not include as much descriptive detail compared to the postinstructional responses. The students' responses regarding their explanation of the lunar phases also indicated a change from pre- to postinstruction. A summary of the four participants' individual conceptions on the pre- and postinstructional instruments is presented here to compare the two. The summaries provide an overall picture as to how the students' ideas changed over time.

On the preinstructional instruments, Dale indicated an awareness that the moon revolves around the earth. He also believed that the moon obtains its light from the sun. The sun is featured in Dale's constructed models; however, he did not describe the actual role that the sun plays in the creation of the lunar phases. In addition, according to Dale, the most important determinant of the lunar phases is one's position on earth relative to the moon's position. For Dale, the moon can be located anywhere in its orbit around the earth to see a full moon as long as

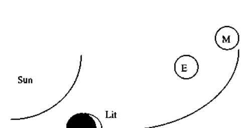

Figure 9. Ann's interview drawing of the gibbous phase.

one's location on earth is directly facing the moon. This view features some scientifically acceptable notions: The moon's revolution of the earth, the sun as the moon's light source, and the importance of the earth's position relative to the moon. However, he also displayed some scientifically inaccurate views. Dale asserted that people on different places on the earth see phases that are opposite each other. For example, Indiana observes a full moon when it directly faces the moon; on that same date, people in Australia observe a new moon since they are facing away from the moon.

On the postinstructional instruments, Dale's conceptions appeared to have changed. He asserted that the sunlight reflected off the moon allows us to see moon phases. In addition, there are portions of the moon that receive light and others that do not. The lighted portions as seen from the earth, determine the moon's shape for the given night. These conceptions are consistent with the scientific perspective; however, Dale also displayed some that were inconsistent. Dale constructed three-dimensional models and drawings during the interview to demonstrate his thinking. The majority of his models and drawings were scientifically accurate, but his drawings of the gibbous and crescent moon featured inaccurately lit portions of the moon. Consequently, it may be that Dale forgot to apply what he explained verbally regarding the lunar phases, or his conceptions lacked information for these lunar phases. In addition, Dale asserted that people on the opposite sides of the earth see the same thing, only it occurs a day behind owing to the earth's rotation. However, during the interview, Dale grappled with his previously held conceptions that featured opposite lunar phases being observed on the same night by different locations on the earth. This comparison of Dale's pre- and postinstructional responses indicates that his conceptions changed and appeared to have incorporated more scientifically accurate aspects (Table 1).

Lois initially displayed views similar to Dale's regarding the explanation for the lunar phases. She indicated that the moon revolves around the earth and one's location on earth is the determining factor for the lunar phase, since it affects the moon's shape. Likewise, she asserted that the moon could be anywhere in its orbit of the earth when a full moon occurs as long as

Table 1
Dale's pre- and postinstructional lunar phase conceptions

	Preinstructional Conceptions	Postinstructional Conceptions
Shape	The first quarter, last quarter, full, and new moon phases are indicated in drawings.	The full, gibbous, crescent, half moon, other half moon, or something in between a gibbous and a crescent are displayed.
Pattern	A major phase (full, half, new, or the other half) is seen approximately every 7 days.	The moon's shape changes every day, but a main phase is seen every week. The entire cycle takes 1 month.
Student perspective	The most important determinant is one's location on earth with respect to the moon's position. The moon can be located in different places in its orbit for the same phase.	One's location on the earth with respect to the positions of the sun and moon determines the lunar phase. Portions of the moon are lit or unlit creating a visible moon from the earth's perspective.
Changes in phenomena	He struggles with the occurence of an eclipse, but reconciles it into his new moon phase.	

Table 2
Lois' pre- and postinstructional lunar phase conceptions

	Preinstructional Conceptions	Postinstructional Conceptions
Shape	Seven phases are indicated in her drawings. The first five are crescent shaped with the right and left side lit; then an approximate circle and a full circle are featured.	Pictures resemble scientifically accurate moon shapes. She features a waning crescent, first quarter, waxing gibbous, full, new, waxing crescent, third quarter, and a waning gibbous in her drawings.
Pattern	The moon rotates through the seven phases. It goes through a series of crescent-shaped moons followed by nearly a circle, then a circle.	The moon does not progress through a cyclical pattern. A given phase could be seen on 2 consecutive nights.
Student perspective	The moon orbits the earth, but the important factor involves one's location on earth in relation to the moon. The same phase can be seen even when the moon is located in different locations in its orbit of the earth.	The sun, earth, and moon are involved in the creation of the lunar phases. The moon's position in its orbit around the earth relative to the sun affects the shape of the moon.
Changes in phenomena	The occurrence of day and night seems to interfere with the phase that is experienced. Two places on the earth see different moon shapes on the same night.	

one's position on the earth directly faces the moon. Interestingly, Lois did not include a description of the sun's role in the process. In fact, her initial drawings did not even include a sun. Like Dale, these views have aspects that are scientifically accurate. However, they are also inaccurate since it is not possible to observe a full moon in all its locations around the earth. Lois' ideas changed from pre- to postinstruction regarding how the lunar phases occur. She stated that the moon revolves around the earth. In addition, her drawings indicated that she was aware that the relative positions of the sun, earth, and moon determine the lunar phases. Lois checked her drawings by constructing three-dimensional models; she drew the sun–earth–moon positions, then checked what one would see from the earth's perspective. In other words, she physically moved herself to a position so that she could observe the Styrofoam moon from the Styrofoam earth's position. Lois appeared to understand the role that the earth's position relative to the sun and moon plays in the creation of the lunar phases. Consequently, it appeared that Lois' conceptions featured more scientifically accurate aspects compared to her preinstructional conceptions (Table 2).

Initially, Ann's views were inconsistent with the scientific view. She explained that cloud coverage creates the lunar phases. As a result, according to Ann, one can observe different phases of the moon on the same night depending on weather conditions. Ann initially stated that the moon goes around the earth, but later she changed it so that the earth orbits the moon. However, she was unable to explain how this revolution process determines the lunar phases. Consequently, Ann's ideas were divergent from the scientifically accepted view. Following the instructional period, Ann's responses indicated that she held a view that was similar to Dale and Lois. Her drawings, verbal explanations, and constructed three-dimensional models indicated that she was aware that the moon revolves around the earth. She also accurately explained the lit/unlit portions of the moon with regard to the side that is facing the sun. In addition, her re-

Table 3
Ann's pre- and postinstructional conceptions

	Preinstructional Conceptions	Postinstructional Conceptions
Shape	Four phases are indicated: "clear" (nothing is seen), "dark" (full circle is seen), half moon, and a "banana" shape.	There are various phases: a full moon, a half moon, almost full, and various stages between these phases.
Pattern	There is no pattern for the moon's shapes since it depends on the weather.	The moon is mostly the same day to day, but from week to week, one can see different phases. It gets "bigger and bigger and smaller and smaller."
Student perspective	Cloud coverage creates the lunar phases. The earth's revolution also plays some part in the process, but it is not clear how.	The moon's revolution around the earth plays a part in creating lit/unlit portions of the moon. The sun plays a role in the lunar phases. The earth's perspectives relative to the sun and moon helps determine the lunar phase experienced.
Changes in phenemena	It is possible to see different phases of the moon on the same night.	

sponses indicated an awareness that the sun, earth, and moon positions determine the lunar phases. Similar to Dale, she showed an inconsistency in her drawing for the gibbous phase, producing an inaccurate shape and lit portion of the moon for the given sun–earth–moon positions. However, she might not have applied what she had previously described and displayed through models, words, and drawings; or it could be that this area was not incorporated into her cognitive framework as well as the other phases. The differences between pre- and postinstruction indicated that Ann's conceptions of the lunar phases incorporated scientifically accepted aspects (Table 3).

Cal initially explained that the lunar phases are caused by the moon going around the earth. This notion is consistent with the scientific view; however, it is also lacking much detail. Following instruction, Cal asserted that the sun makes the moon's light. In addition, he also featured models that displayed the moon revolving around the earth. This indicates that Cal was aware that the moon orbits the earth. However, Cal's constructed sun–earth–moon models were scientifically inaccurate for the given lunar phases. He displayed two different models for the same lunar phase, which is scientifically inaccurate. Furthermore, Cal showed mismatched lunar phases for the given sun–earth–moon positions, since the lit portions of the moon were inaccurate for their corresponding models. Cal's responses indicated that he had adopted some aspects that were scientifically accurate; he also lacked some important information regarding the lunar phases (Table 4).

Conclusions

This study investigated students' conceptions of the lunar phases. It explored the way that students' ideas were represented through verbal and written responses, drawings, and three-dimensional models. In a sense, it explored students' constructed conceptions prior to and fol-

Table 4
Cal's pre- and postinstructional conceptions

	Preinstructional Conceptions	Postinstructional Conceptions
Shape	Three phases are indicated in his drawings: full, half moon and crescent moon. He also mentions the new moon, but does not clarify his meaning.	Six different shapes are featured in his drawings: full first quarter, gibbous, new, last quarter, and crescent. He does not give them labels.
Pattern	There is a set sequence of shapes: full, half, and crescent; then it repeats this process.	He does not provide information.
Student perspective	The moon orbits the earth, but no clarification is offered.	The moon receives light from the sun. The models feature the moon in different locations, but it is not further clarified.

lowing the presentation of the scientific perspective of the lunar phases. Several assertions emerged which addressed the guiding research questions. First, students conceptions of the lunar phases are divergent from the scientific perspective, yet they also have components that are consistent with it. It appears that some students adopted some scientific information such as the moon's revolution around the earth or the observed shapes of the moon. However, they also constructed their own notions that are inconsistent with the scientific view. For example, one student asserted that cloud coverage determines the lunar phases, whereas others believed that one's location on the earth with respect to the moon's position determines the lunar phase. For these students, it is possible for a full moon to occur at anytime regardless of the moon's position within the earth's orbit. In addition, the findings of this study indicate that the students' conceptions of the lunar phases changed in some ways following instruction. For instance, three of the students displayed models and drawings which represent the integration of the earth's perspective relative to the positions of the sun and moon. This view appears to be consistent with the scientific perspective; however, two of the students also presented discrepant models for the gibbous and/or crescent lunar phase. Therefore, it appears that many of the students were capable of changing their conceptions, but each seemed to progress at an individual rate.

The third-grade students had difficulty representing the appropriate lunar phase for given sun–earth–moon models. Some of the phases seemed more challenging because they featured the reversal of the lit^{n}lit portions of the moon as seen from the earth's perspective. Students were asked to identify the right or left portion as lit or unlit to facilitate their two-dimensional drawings displaying the lunar phases. However, students continued to struggle with the reversal even after they received help. Similarly, Callison and Wright (1993) found that their participants also struggled with the complexity of models. Consequently, the lunar phases could be considered inappropriate for the third-grade level oing to the complexity of the phenomenon itself as well as that of the simulated models.

The third-grade students also seemed to maintain some aspects of their original conceptions representing the resilience of their ideas. For instance, one student continued to grapple with the occurrence of the lunar phases on the same date for different locations on the earth. This student reasserted his notion that different places on the earth see different shapes of the moon on the same date. However, later he revised this notion so that it fit with his reconstructed conceptual framework. The fact that he mentally struggled with this notion indicates that it was still ingrained in his cognitive framework, but he was beginning to reconstruct his conceptions so that they were more consistent with the scientific view.

This study confirmed that the topic of lunar phases is a complex concept to master. Students displayed concepts that interfered with their conceptual understanding of the lunar phases. For instance, the occurrence of an eclipse presented a situation that seemed to contradict the lunar phases unless one incorporated it into the new moon phase. For some, the earth's rotation interfered with the students' conceptions of how the lunar phases occur. Finally, the students seemed to have difficulty incorporating all of these ideas into their conceptual framework for the lunar phases.

After students had the opportunity to manipulate models of the sun–earth–moon systems to investigate the lunar phases, they were assessed once again to determine their conceptions. Changes in the students' responses indicate that these activities presented conceptual conflict to some of the students. Therefore, these changes from pre- to postinstructional assessment suggest that some of the participants were able to make conceptual changes. The presence of more scientifically accurate aspects in the students' postinstructional responses indicates that the repeated instructional activities facilitated the change in students' ideas.

However, after the instructional phase, some of the students continued to display aspects that were scientifically inaccurate. For example, Dale and Ann constructed drawings that did not scientifically match the sun–earth–moon positioning. This finding suggests that students may continue to hold views that are inconsistent with the scientific view even after providing a view that is scientifically accurate. It appears that students adopted some aspects of the scientific perspective; however, there are others that were not assimilated into their developing cognitive framework at that time. This has important implications for lunar phase instruction.

Educational Implications

Students' conceptions of lunar phases are products of their attempts to make sense of their world. The students' ideas are often influenced by their prior observations or experiences. These prior experiences can occur inside and outside of the classroom from the following sources: television, trade books, observations of the moon, textbooks, and discussions with others. In addition, the form of instruction could also influence the form that students' conceptions take.

The Silver Burdett textbook (Mallinson et al., 1987) presents the concepts of lunar phases through the written word and illustrations of the moon shape linked with the appropriate sun–earth–moon positions. The information is presented as a set of facts for students to incorporate into their cognitive frameworks without modification. However, this study with third-grade students questions the sole use of the textbook. Students in this study continued to display ideas that were inconsistent with the scientifically accepted perspective even after they constructed and manipulated models of the sun–earth–moon system. Consequently, it is questionable whether the textbook's approach would effectively allow the students to enhance their understanding of the lunar phase phenomena, since it does not feature active involvement on the student's part.

It is also likely that the teacher is unaware of the conceptions that the students bring to the classroom. Since students' conceptions may influence future learning, it is imperative that teachers design and implement activities which delve into the students' ideas, then challenge those that are scientifically inaccurate. If teachers understand student conceptions, activities can be designed to present a contradictory view which challenges the students' misconceptions. These activities should allow students to test their own ideas as well as examine the scientifically accepted perspective. In this way, students may recognize the inaccuracy of their conceptions and adapt them so that their notions become more similar to the scientific view.

An additional implication from this study involves the appropriateness of the topic of the lunar phases at the third-grade level. The findings of this study indicate that some of the students were capable of enriching their conceptual understanding of the lunar phases. However, three of the participants also continued to display views that were scientifically inaccurate. Perhaps the topic of lunar phases is too complex for third-grade students, since these three students continued to display inaccurate information. Consequently, educators may want to further explore the appropriateness of lunar phase content at this age level.

Finally, many schools feature spiraling curricula in which the concepts are studied progressively in more detail as the children progress through the grade levels. At all ages, students could potentially adopt conceptions that are scientifically inaccurate even when they are exposed to scientifically accurate information which is counter to their beliefs. Research in the area of alternative conceptions indicates that these scientifically inaccurate notions are often very resistant to change (Driver & Oldham, 1986; Driver et al., 1994; Furnham, 1992; Osborne & Cosgrove, 1983; Tobin & Tippins, 1993). Consequently, curriculum developers need to reconsider the concepts that are featured at the given grade levels as well as the instructional methods that are used. In this way, conceptual development could be facilitated in such a way that students would be likely to accommodate scientifically acceptable perspectives.

The National Research Council also published a document which lends support to the inappropriateness of featuring the lunar phase concepts at the third-grade level. The *National Science Education Standards* (1996) stated,

> 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 shapes over several weeks. These understandings should be confined to observations, descriptions, and finding patterns. Attempting to extend this understanding into explanations using models will be limited by the inability of young children to understand that earth is approximately spherical. They also have little understanding of gravity and usually have misconceptions about the properties of light that allow us to see objects such as the moon. (pp. 130, 134)

The study with the third-grade students detected that some changes occurred regarding the students' conceptions of the moon phases; however, they also continued to display inconsistency with the scientific perspective. Perhaps these students are not developmentally and academically prepared for the complex conception of the lunar phase phenomena.

Prior studies (Baxter, 1989; Bisard et al., 1994; Callison & Wright, 1993; Dai & Capie, 1990; Kuethe, 1963; Schoon, 1992) detected alternative conceptions for the lunar phases at all levels from elementary to the university level and beyond. Many of Callison and Wright's (1993) preservice teachers displayed ideas that were inconsistent with the scientific view. In addition, some of them shifted their conceptions following instruction; however, many continued to display ideas that were scientifically inaccurate, while others only adopted aspects of the scientific view. Dai and Capie (1990) also identified alternative conceptions for the lunar phases in their population of preservice teachers. Interestingly, teachers with the responsibility of educating children displayed alternative views of the lunar phases. It is interesting to note that the concept of the lunar phases is featured at the elementary level, yet many older individuals display alternative conceptions even after receiving instruction. These studies, in addition to this one, indicate the need for change regarding the grade level and instructional method appropriate for the lunar phase concepts.

References

American Association for the Advancement of Science. (1993). Benchmarks for science literacy. New York: Oxford University Press.

Ault, C.R. (1984). The everyday perspective and exceedingly unobvious meaning. Journal of Geological Education, 32, 89–91.

Baxter, J. (1989). Children's understanding of familiar astronomical events. International Journal of Science Education, 11, 502–513.

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, 3842.

Callison, P.L., & Wright, E.L. (1993). The effect of teaching strategies using models on preservice elementary teachers' conceptions about relationships. Paper presented at the National Association for Research in Science Teaching annual meeting, Atlanta, GA. (ERIC Document Reproduction Services ED 360-171)

Dai, M.F., & Capie, W. (1990). Misconceptions about the moon held by preservice teachers in Taiwan. Paper presented at the National Association for Research in Science Teaching annual meeting, Atlanta, GA. (ERIC Document Reproduction Services ED 325-327)

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. Educational Researcher, 23, 5–12.

Driver, R., & Oldham, V. (1986). A constructivist approach to curriculum development in science. Studies in Science Education, 13, 105–122.

Fumham, A. (1992). Lay understanding of science: Young people and adults' ideas of scientific concepts. Studies in Science Education, 20, 29–64.

Geertz, C. (1983). Local knowledge: Further essays in interpretive anthropology. New York: Basic Books.

Hewson, P.W. (198 1). A conceptual change approach to learning science. European Journal of Science Education, 3, 383–396.

Huberman, A.M., & Miles, M.B. (1994). Data management and analysis methods. In N.K. Denzin & Y.S. Lincoln (Eds.), Handbook of qualitative research (pp. 428–444). Thousand Oaks, CA: Sage.

Janesick, V.J. (1994). The dance of qualitative research design: Metaphor, methodology, and meaning. In N.K. Denzin & Y.S. Lincoln (Eds.), Handbook of qualitative research (pp. 209–219). Thousand Oaks, CA: Sage.

Kuethe, J.L. (1963). Science concepts: A study of "sophisticated" errors. Science Education, 47, 361–364.

Mali, G.B., & Howe, A. (1979). Development of earth and gravity concepts among Nepali children. Science Education, 63, 685–691.

Mallinson, G.G., Mallinson, J.B., Smallwood, W.L., & Valentino, C. (1987). Silver Burdett science Grade three. Morristown, NJ: Silver Burdett.

Marshall, C., & Rossman, G.B. (1995). Designing qualitative research (2nd ed.). Thousand Oaks, CA: Sage.

National Research Council. (1996). National science education standards. Washington, DC: National Academic Press.

Nussbaum, J. (1979). Children's conceptions of the earth as a cosmic body: A cross age study. Science Education, 63, 83–93.

Osborne, R.J., & Cosgrove, M.M. (1983). Children's conceptions of the changes of state of water. Journal of Research in Science Teaching, 20, 825–838.

Patton, M.Q. (1990). Qualitative evaluation and research methods (2nd ed.). Newbury Park, CA: Sage.

Philips, W.C. (1991). Earth science misconceptions. The Science Teacher, 58, 21–23.

Sadler, P.M. (1987). Misconceptions in astronomy. In Proceedings of the Second International Seminar on Misconceptions and Mathematics, Cornell University, Ithaca, NY, pp. 422–425.

Saunders, W.L. (1992). The constructivist perspective: Implications and teaching strategies for science. School Science and Mathematics, 92, 136–140.

Schoon, K.J. (1992). Students' alternative conceptions of earth and space. Journal of Geological Education, 40, 209–214.

Schwandt, T.A. (1994). Constructivist, interpretivist approaches to human inquiry. In N.K. Denzin & Y.S. Lincoln (Eds.), Handbook of qualitative research (pp. 118–137). Thousand Oaks, CA: Sage.

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.

Tobin, K., & Tippins, D. (1993) Constructivism as a referent for teaching and learning. In K. Tobin (Ed.), The practice of constructivism in science education. Washington, DC: American Association for the Advancement of Science.

von Glasersfeld, E. (1993). Questions and answers about radical constructivism. In K. Tobin (Ed.), The practice of constructivism in science education. Washington, DC: American Association for the Advancement of Science.

Wittrock, M.C. (1974). Learning as a generative process. Educational Psychology, 11, 86–95.