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ABSTRACT

The paper identifies possible factors associated with changes in style and presentation of diagrams of lunar phases and eclipses in school textbooks and other resources. Science curriculum resource materials used extensively during the past two hundred and fifty years in North America and Australia provide insights into teaching and learning of science, with particular emphasis on primary and lower secondary grades. Several different "lenses" are employed to provide a range of complementary perspectives (historical, geographical, cultural, epistemological, and pedagogical) and to discuss implications for teaching and these topics. (Contains 55 references.) (Author/ASK)

Lunar Shapes and Shadows: What are the sources of our instructional ideas?

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The paper identifies possible factors associated with changes in style and presentation of diagrams of lunar phases and eclipses in school textbooks and other resources. Science curriculum resource materials used extensively during the past two hundred and fifty years in North America and in Australia provide insights into teaching and learning of science, with particular emphasis on primary and lower secondary grades. Several different "lenses" are employed to provide a range of complementary perspectives (historical, geographical, cultural, epistemological and pedagogical) and to discuss implications for teaching and these topics.

Lunar Shapes

The moon was probably one of the first objects to be studied thousands of years ago when astronomy was first being developed (Fraknoi, 1996). Its constantly changing shape is obvious to a careful observer and every group of humans on earth has worked out the monthly cycle of the moon. This long-standing human interest in the phases of the moon has continued to the present, and is one of the most common science topics taught throughout the world, (Engerstr6m, 1991; Ministry of Education, 1993; Queensland School Curriculum Council, 1999; Rutherford & Ahlgren, 1990).

Sources of Instructional Ideas

The same diagram has been used to explain the *phases of the moon* since at least 1756 (Ferguson, 1756). In this standard diagram, (Figure 1), the relative position of the moon with respect to the earth and sun determines what part of the moon is lit by the sun, and therefore the "phase" of the moon we observe from earth. The diagram focuses instruction on a limited number of topics needed to understand phases of the moon: the relative position of the earth, sun, and moon; the names of the phases; the idea that the moon has no light of its own, and only reflects sunlight; the times the various phases rise or set, and: occasionally, the rotation of the moon.

FIGURE 1 HERE

Teachers, however, are always looking for new ideas to improve their understanding of the subjects they teach and to improve their students' learning. After all these years, with such a common topic, one wonders if there is anything new to learn or teach? If there are potential sources for expanding instruction on phases of the moon, where can they be found?

Problems with the "Standard" Moon Diagram

The traditional moon diagram is both ubiquitous and problematic. There are at least three obvious problems with the diagram. First, the diagram mixes two views. One view is of the earth, sun, and moon as seen from space, commonly shown from above the North Pole. The other view is of each individual moon phase, as it would look to an observer on earth. In addition to space-based and earth-based views, the diagram confuses time. It shows both a complete month's cycle of the moon, and the daily observations of each phase. Finally, the diagram distorts both the relative sizes of the objects and the relative distances between them.

The space-based view is often vague. Rarely is there any indication of whether the perspective is from space above the North or South Pole. Often, no mention is made of the direction of the moon's orbit. On one occasion, in a children's book specifically written to explain the phases of the moon, the view of the earth was from above the equator, with the moon revolving from North to South Pole *(1)*

Students commonly demonstrate problems with the diagram. A university student asked, "Does the moon go through all phases each night, as it goes around the earth?' An elementary school child asked, "How can sunlight hit the moon if we are in the dark?"

Henderson (1999), believes teachers understand "that the diagram represents the moon in different positions as it orbits the Earth," because they tie conceptual knowledge to the diagram. Students are confused by diagrams that show the one object in the diagram changing over time while another object in the diagram is represented as unchanging over time. In Henderson's diagram the eight pictures of the moon are named, and he asks, "Are there really eight (or six or nine) moons?"

Engerstrom (1991) thinks the diagram contains several problems that foster misconceptions among children. He claims many children and adults think the earth's shadow causes the phases of the moon because of the scale errors in the diagram and the fact that lunar eclipses are not taught at the same time as phases of the moon. He also thinks giving the students the finished diagram, and not letting them develop it from observations, causes a problem.

Persistence of Instructional Ideas

These problems apparently have not had much of an effect on the prolific use of the diagram. It is easy to draw, and focuses instruction on specific and therefore testable knowledge. The diagram provides a sense of security that we know the content and children just have to learn it, as we did, to understand phases of the moon. This is an example of *Instructional History* (Cohen, 1995) that sets the agenda for what and how we teach *Phases of the Moon.* We can be aware of the difficulties created by the diagram, but it was the diagram most of us used to learn this topic. As we continue to use the diagram, we need to ask ourselves how effective is it with our instruction?

Lunar Shadows and Misconceptions

While humans have observed the changing shapes of the moon for thousands of years, and worked out its cycle, adults and children today have difficulty explaining the phases, even after instruction, (Arons, 1980; Callison & Wright, 1993; Cohen, 1982; Engerstr6m, 1991; Schoon, 1992; Stahly, Krockover & Shephardson, 1999; Targen, 1987). It is common for adults, preservice teachers, and children to claim that the earth's shadow falling on the moon causes the phases. In addition, common observations, such as viewing the moon during the day, are considered unexplainable by many. What was understandable to our ancestors appears to have become incomprehensible to many of us today.

The incorrect concepts expressed by adults and children provide an interesting perspective from which to view the efficacy of instruction. As Engerstrom (1991) suggests, changing instruction to include eclipses might help. We think the range of children's concepts provides us with hints about what the students might be thinking and how they differ from adult views. It is possible that we can learn from the students' misconceptions. In the award winning video, *A Private Universe,* (Schneps, 1988) a middle school student is asked if the moon changes shape. The student replies, "No. It is always round." One source of "new' ideas about appropriate instruction might come from students' perceptions and explanations.

Expanding concepts about phases of the moon from historical textbooks

Seeing the diagram we currently use in old textbooks helps us to feel confident that we really know what we are doing. After all, we have been teaching phases of the moon in this way for hundreds of years. However, there are important differences between the old and new textbooks. Currently, we often find a "separation of school learning from experience and cognition outside the school," (EngerstrOm, 1991). This would have been a disaster in the distant past. When the older books were written and the diagram created, navigation was critical and not standardised. Longitude, for example was measured by the English from London, by the French from of Paris, and by the Americans from Philadelphia (Bingham, 1805). In addition, time and seasons were local since the books were written before standard time zones. People's lives were dependent on understanding their own natural environment. Early textbook authors took time to explain how data were then collected, organized and used, making the instruction relevant to the local area. It seems that the old textbook writers and teachers did not take for granted their students' knowledge of the earth, moon, sun, and stars.

This recognition of what students may "not" know shows up in the 18^{th} & 19^{th} century, and early 20th century textbooks. Pauley (1831) anticipated the question asked earlier in this paper about the seeing the moon at night. Pauley explained, "You must remember, that although the sun is gone from us at night, yet it really exists at a great distance round the other side of the earth. There it is always shining; and so lights up the moon, and renders it visible to us."

While the old books use the same moon diagram, they spend much more time preparing the students to visualise the various perspectives. Rather than providing a diagram to memorize, the early authors build up to and explained the development of the diagram, providing the background information needed to conceptualise the diagram. They then spend pages explaining the diagram. The following are examples of new ideas, or expansions of problematic ideas about teaching phases of the moon, that come from the old textbooks. At the end of this paper we will relate these examples to instructional ideas.

Relative Position and Motion. Worchester (1831) provided information on relative position. He first explained that the earth is a ball, (see geography section, page 4). Using the example of a fly on the ball, he wrote, if the ball were rotating, to the fly the sun would appear to move. He then related the example to common relative motion. He said, when you ride in a boat or coach, "the trees and houses, and fences which you pass appear to move in the opposite direction."

Relative Size and Distance. Showing astronomical sizes and distances on one diagram is virtually impossible. Moseley, (1919), shows both the relative sizes of the planets and their relative distances from the sun in one diagram (Figure 2). The top set of circles shows the relative size of the planets. The bottom set of circles shows the relative size of the sun as seen from each planet.

FIGURE 2 HERE

The shape of lunar and terrestrial shadows. Current texts show the shadow of the earth and moon as two-dimensional triangles, without any discussion about why the shadows are drawn in this shape. Several older texts use diagrams to discuss the shape of the shadows of the moon and the earth. In

Figure 3, Olmstead (1866) compares what the shadow of the earth and moon would look like if the sun was smaller, the same size, or larger than the earth and moon.

FIGURE 3 HERE

The moon reflects light. The idea that the moon has no light of its own and shines by reflected light is a key concept included in all instruction on phases of the moon. Almost all of the recent textbooks and articles merely state this information as a fact without citing any evidence. Ferguson (1812)2 not only discusses why we know the moon reflects light, but writes it in a manner where the explanation comes from a child.

Ferguson's text is written as a dialogue between a brother who has studied astronomy at a university and his younger sister. Throughout the text the brother and sister pose questions. Occasionally the sister asks a question or provides an explanation that surprises the brother. For the first part of the explanation of phases of the moon the brother uses a candle and small ivory globe to represent the sun and the moon. The brother carries the globe (moon) around his sister's head, which represents the earth. At various places in the circuit he stops and they discuss the light on the globe and the shape observed by the sister. After the demonstration the sister says, "I think, it also shows that the moon does not shine by any light of her own; but only by reflecting, the sun's light that falls upon her. For, if she shone by her own light, we should always face her round, like the sun." Ferguson then uses the standard diagram to carefully explain the phases of the moon one more time.

Hands-on experiences. The old texts included many demonstrations, and several were exactly like those used today. Ferguson, (1756 and in the example in the paragraph above), used a candle and a ball to show what the phases of the moon would look like. Others followed suit with some illustrating how an entire class could be taught the phases of the moon. In our search for variety in the approaches to teaching phases of the moon we found one example from 1986, that was clearly copied from an older book without any sense of adaptation to the current environment. It asked teachers to find an oil lamp to serve as a source of light to demonstrate the phases of the moon.

Orbit of the Moon around the Sun. Proctor (1878) anticipated the question raised earlier by Henderson (1999), in explaining that the diagram is drawn from a perspective where the earth is standing still. The moon in the traditional diagram, says Proctor *(1878),* is revolving around a stationary earth (see Figure 4). Smith (1875) includes the orbit of the earth and moon around the sun in a slightly different manner. In Figure 5, Smith shows the earth and all the phases of the moon at four different locations around the sun. Mattison (1872) actually draws the orbit of the moon around the sun. A more recent textbook from Australia (Nuclear Research Foundation, 1964) also suggests we can understand the phases of the moon more completely, if we consider its orbit around the sun.

FIGURE 4 & 5 HERE

Phases of the moon and geography

Geography was at one time a very important and popular school subject. Early books (Smiley, 1830) helped children understand and read maps. Later books were built around the idea that geography for children in the third to fifth year should, "be a practical study of man's physical surroundings in their relations to him," (Redway and Hinman, 1901). Geography has always integrated both the local and the universal. In understanding the phases of the moon it is important to look at the topic from both the Southern and Northern Hemispheres.

Because of the importance of, and dependence on the traditional moon diagram, it is not uncommon to find one hemisphere's text using the other hemisphere's illustrations of the phases of the moon.

Engerstr6m, (1991), discusses phases of the moon from Finland, with a diagram showing the traditional diagram as viewed from space above the South Pole. Henderson (1999) has a diagram from a 1984 Australian elementary school textbook showing the diagram from above the North Pole. It's an example of Instructional History where the diagram has taken on a life of its own which is more important observations or accuracy.

But even direct observations about what they see outside might not help children form a geographic perspective. Misconception studies indicate that children have many problems with observations. Some children believe that where you stand determines what phase you see (Stahley, et al, 1999). Other children believe the earth is round and flat like a plate or spherical, with people living inside on the flat surface (Nussbaum, 1979). In spite of research evidence to the contrary, we spend little time helping children make sense of the size and shape of the earth. It is as if the shape of the earth, scale, and relative position are not issues that belong with teaching about phases of the moon.

The shape of the earth. The older texts were written from the perspective that the shape of the earth was not always obvious to the reader. Before they would state a fact, such as the shape of the earth, the authors would provide broad, underlying concepts. Worchester (1831) begins by carefully defining a sphere, "Your ball is a globe or sphere. Everything, whether great or small, that is shaped like a ball, is called a *globe* or *sphere.* An apple, an orange, this great Earth on which we live, the Moon, the Planets, and the Sun are all shaped in nearly the same manner, and we therefore say they are *globular or spherical" (Italics* in original). He goes on to discuss what might also seem obvious, that people can only see a small part of the earth. "The Earth on which we live does not appear like a globe when we look at it; but it is so large, that we can see only a very small part of it," (Worchester, 1831).

Bingham (1805) brings up another interesting basic concept when he asks, "What is an artificial globe?" His answer, "A round body on which all parts of the earth are represented." It is interesting that he and several other authors of the older books made a point of distinguishing between the globe on which we live and the "artificial" globe we have in schools and homes.

Jackson (1894) provides five different explanations as to why we know the earth is a sphere. But the explanations are not just listed as if they were obvious. After the third explanation Jackson adds a typical comment, found in many older texts, questioning the information provided. He says, "It may be thought that the three proofs given above do not show *positively* that the earth is spherical -- that it might be some other rounding form, like that of an egg, for example, without affecting the appearances described." So in addition to providing observational evidence, the old books asked readers to make sure they can believe and justify the data. In the section on Practical applications on page 8 XXX we provide several explanations on how we know the earth is a sphere

The current environment and the development of curriculum

In looking at old textbooks it is important to consider the environment in which they were written. With current instructional approaches it is equally important to consider how contemporary culture might affect what is included in an explanation. The old texts were clearly written in a very different setting. Today, we have students who can take virtual trips to other planets, watch television programs and movies about space travel, and listen to news reports of transmissions from scientific instruments on other planets. There are even opportunities for students to work with current data on-line and collect data from telescopes from great distances. While there are interesting computer simulations, many commercially available computer encyclopedias still use the traditional moon diagram without any clarifications. We often assume that children are more sophisticated about time and space than children fifty or two hundred and fifty years ago. But, they are still children and many may not really believe the earth is a sphere (Nussbaum, 1979).

Phases of the moon and different cultures

"The Moon offers the easiest opportunity to transform enjoyment of the majesty of the heavens into a predictive science," (Fraknoi, 1996). Every culture in the world has observed the moon's monthly cycle and it serves as a yearly calendar for many diverse groups. While the observations are similar, stories associated with the moon are unique for each culture (Hulley,1996; Moon names website, 1999; Riddle, 1993; Riddle, 1996).

The fact that different cultures have different moon stories is easy to understand and it is appropriate to use a variety of these stories in all classes. What is more difficult to realize is that our own children represent a unique culture. Starting with the books we read to young children, we begin to provide a wide range of real and imaginary ideas on the moon. These books, which children love, talk about the moon worrying about what clothes it will wear, a father getting the moon for his daughter, and a moon that can be as big, as far away, and made of a variety of substances, (Brown, 1975; Carle, 1986; Thurber, 1940; Willard, 1983). This "children's culture" provided by books and story telling places the moon's phases in a variety of setting unrelated to direct observations and reality. Perhaps the most difficult issue is how these books ignore direct observations. They may lead to children having more faith in what they believe from storybooks and fantasy than what they observe (Mayer, 1995).

The current culture of textbooks usually allows only accurate information to be provided to the children. However, it is often useful to provide fanciful notions to make a point or expand children's speculation. In 1964 the Nuclear Research Foundation (NRF) designed a high school textbook for New South Wales that included *The Lunar Electricians Theory* as a possible explanation of phases of the moon. They asked the children to suppose there were beings who installed bright lights over the surface of the moon and turned then on and off to create the phases. (This might have made sense in the 19th century when Worchester, (1831), wrote, "There is but little air about the Moon, and probably little water upon it. We could not live there; but it is doubtless a very good world for such people as live there.")

The NRF did bring up the problem of reflection on this electrical moon. They asked the children to, "Suppose, finally, that the moon's surface simply absorbs all of the sunlight falling on it, and reflects no part of it." The text then went on to discuss how you could compare the accuracy of the *Lunar Electricians Theory* with the one based on relative position of earth, moon and sun. In the manner of many of the old textbooks, the reader was given not only information, but also background information about how the data were obtained and how we know they are accurate. In addition this more recent textbook provides questions about additional unexplained information or questions.

They state, "What we have suggested about the moon serves us quite well, but, of course, it is not the whole story. We find that because of other observations, which we have not undertaken, that much more must be added" (Nuclear Research Foundation, 1964).

Phases of the moon and epistemological and pedagogical ideas Historical perspectives

Contemporary pedagogy is based on hundreds of years of tradition, experience and research. We are rightly proud of where we are and where we are going in curriculum development, instruction, teacher education, assessment, and continuing professional development. Many of the 18th century books provide evidence for the pedagogical and epistemological frameworks reflected in current views of curriculum and instruction.

Smiley (1830), saw curriculum and instruction as, "...a judicious selection of the numerous facts of which the science is composed, and their arrangement in such a manner as will enable the student with the least labour to acquire a competent knowledge of the subject." He endeavoured to arrange the subjects in a manner in which they naturally follow each other, and thereby to present, free from the confusion which too generally accompanies works of this nature, a clear and perspicuous view of the whole."

Other authors saw broader educational reasons for science books. Burnap (1822) criticizes those, "Unmindful of the primary objective of education, which is *mental discipline.* " He continues, "Many have been unwilling to afford their children time and opportunity, for acquiring any more scientinfick knowledge, than barely to qualify them for the business, which they designed to pursue. (Spelling and italics in original.) Hooker (1858) goes even further when in the preface to his book he says, "The chief defect in primary instruction, as it is commonly pursued, *is the failure to teach children to think.* Everything is learned almost entirely by rote."

In distinguishing between advanced and elementary texts, Plummer (1873) tells us that elementary texts must be ". . . sufficiently scientific to imbue the youthful mind with a love for the science in its true aspect, and yet at the same time sufficiently easy and free from technical and mathematical reasoning to be read and understood with the imperfect knowledge of pure mathematics, possessed by this class of students." He than adds an interesting note that is found within many older texts, the use of introductory texts as motivators for advanced study. "The whole, however, forms an introduction to the study of Astronomy, which it is hoped may lead some to seek for deeper knowledge in other more advanced works, and in the standard textbooks of the Universities," (Plummer, 1873). Olmstead (1866) provides an example of the differences we observed between older and newer books. He says, with respect to his book, "More particularly, its object is to teach what is known respecting the Sun, Moon, Planets, Comets, and Fixed Stars; and also to explain the methods by which this knowledge is gained."

Contemporary pedagogy

We believe two contemporary theoretical frameworks support our emphasis on the blending of old texts and children's concept research to expand the options for science curriculum and instruction. The first framework comes from Osborne, Freyberg and Tasker (1982), who classify the science curriculum into four categories from the *official* through the *children's* curriculum. These categories provide locations for the "new" ideas from the old texts within the official curriculum and for children's concepts and some old textbook material within the children's curriculum. This framework encourages feedback from children's ideas and old textbooks to inform and expand the dimensions of the official curriculum and create a dynamic, evolving official curriculum.

The second framework comes from Gardner's (1993) study of creativity as exemplified by the lives of seven twentieth century individuals who changed their disciplines. A key theme in his work is *"the relationship between the child and the adult creator."* His observations about Einstein supports our emphasis on a broad understanding of the discipline enhanced by old textbooks and the child's perspective provided by interview studies. In order to change the direction of a discipline like physics around 1900, required, "...someone steeped in the findings of recent physics, but not yet too entrenched in its current points of view — a mind at once young and mature," (Gardner, 1993, P101).

To raise the fundamental questions necessary to change the direction of the science curriculum we need to integrate the mature and young views of the discipline. Osborne, Freyberg and Tasker (1982) and Gardner (1993) provide frameworks that support these two seemingly disparate approaches by supporting a model of continuous review and revision of curriculum and instruction. These frameworks will help foster the recent calls for meaningful content, learning to learn, integrating all aspects of science content, and continuous teacher development, (van der Akker, 1998).

Categories of curriculum

In the design of the research that led to their popular book, *Learning in Science,* (Osborne and Freyberg, 1985) Osborne, Freyberg, and Tasker (1982) described four different categories of curriculum. These were:

(i) the official curriculum

(ii) the teachers curriculum

(iii) the actual curriculum

(iv) the students' curriculum

(Osborne, Freyberg and Tasker, 1982,

(official transmitted)

(teachers' intentions)

(teachers' actions)

(students' received)" Page 10.)

All four categories are critical if we are continually to improve curriculum. Professional organizations, state and federal agencies, school corporations, and book publishers are the groups devoted to concerns of the official curriculum. The new standards would be considered part of the official curriculum. Teachers, schools, and teacher education programs adapt the official curriculum to the teacher's curriculum, to meet the specific needs of students. Lesson plans, teachers' journals, professional meetings and some professional development reflect examples of the teachers' curriculum. The actual curriculum, including the hidden curriculum, and the students' curriculum, what the students take away from instruction, are studied by some educational researchers and in some teacher education programs. Children's science concept research would be an example of the information related to the students' curriculum, as would the idea of "children's science" used by Gilbert, Osborne and Fensham (1982).

Whenever there are a limited number of categories, especially if they are numbered, there is the potential to consider the first more important than the second. With these categories of curriculum, it looks like a hierarchy is implied. Some might think the official curriculum is most important since it has a long history and contains input from many "specialists." We believe Osborne, Freyberg and Tasker (1982) treat the four categories equally. With van den Akker (1998), we believe the different representations are necessary when discussing and comparing curriculum innovations.

The official curriculum is important because it provides an overall conception of what is to be taught and usually includes the specific topics to be included at each developmental level. But, it is only the best approximation at the time it was written. The official curriculum can evolve as feedback is provided by the teachers', the actual, the children's curriculum, and "new" material from old textbooks. Teachers are usually more concerned with how the official curriculum can be made appropriate for their students. The students' curriculum provides us with information about how the children make sense of our instruction. It can be a source of new instructional ideas.

There are other classifications of curriculum and van den Akker (1998) presents a model with six:

ideal, formal, perceived, operational, experiential and attained. We believe, for our purposes that his six can be abbreviated to the four we use. van den Akker (1998) does bring up other considerations that are relevant to our discussions. For example, "what knowledge is of most worth for the science curriculum" and "how science curriculum programs and materials should be developed and implemented."

Integrating mature science and childlike wonder A major component of the scientific enterprise involves creativity. As part of science, it should have a place within the development of the science curriculum. Gardner's *Creating Minds* (1993) provides a different way to validate our use of the curriculum framework of Osborne, Freyberg, and Tasker (1982). In this book, Gardner (1993) studies seven individuals who had an impact on the twentieth century; Freud, Einstein, Picasso, Stravinsky, Eliot, Graham, and Gandhi. He uses three organising themes to structure the book: 1. The relationship between the child and the adult creator; 2. The relationship between the creator and other individuals, and; 3. The relationship between the creator and work in a domain. These themes provide a different way to integrate the four classifications of the curriculum with children's science concepts and the concepts in old textbooks.

Gardner includes both the idea that "adult creativity has its roots in the childhood of the creator," and that the "creators were able to maintain the wonder and openness of young children throughout their lives." From our perspective this provides a critical reason to continue to study the children's curriculum. While a few adults can maintain the curiosity of a child in some areas, most adults are frequently surprised by children's statements.

It is interesting that Einstein knew Piaget and suggested that Piaget investigate children's intuitive notions, which Gardner calls Piaget's "most illuminating lines of research," (Gardner, 1993). It was this area of Piaget's research that formed the basis of many science education studies of children's concepts (Pines, Novak, Posner, & VanKirk, 1978). Of specific application for this paper is the idea that Gardner's themes raise questions about teachers and teacher education. From Gardner's position, we need to examine "the connection between the kinds of questions a gifted child ponders, and the nature of training and thinking required for the adult practitioner to answer such questions."

Gardner's organising themes provide an expanded idea of a discipline and are especially important in looking at the official and teacher's curriculum and how they might be affected by the children's curriculum. His work is also critical in relating creativity in several disciplines to creativity in science education. The creators in his study first mastered the work in their domain, as we would start with the official curriculum. However, the creators' relationships with that domain became problematic and they began to create "new symbol systems." Our studies of children's science should affect our perceptions not only of how children learn, but also how we view the official curriculum. The old textbooks provide a broader range of ideas to consider as part of the official curriculum.

Curriculum, especially in science, is abstract and remains an elusive problem, claims van den Akker (1998). He continues, while "science curriculum change is complex but not impossible." We believe that the material in textbooks over the last two hundred and fifty years and children's science concepts can lead to a wider range of activities and open new understandings for ourselves and our students.

Expanding activities on Phases of the moon

In this section we provide a number of activities we believe can expand our current approach to teaching phases of the moon. They come from the reviewed textbooks, research on children's science concepts, and the ideas the textbooks and children's concepts generate.

Anticipating children's questions

One of the oldest ideas about teaching is to start from where the children's are, (Ausubel, 1967). Earlier we provided examples from old books whose authors seemed to be able to anticipate children's questions. Some teachers seem to have a real skill in understanding their students' perceptions and conceptions. For the rest of us, we have to learn to listen to student questions and answers more carefully. We have to learn to probe their statements to see what they are really saying or asking. This is where the children's and teacher's curriculums become important.

Relative position and motion

The majority of science concepts in astronomy involve three spatial dimensions. Yet most representations in books are shown as two-dimensional diagrams. The example from Worchester (1831), provided earlier, can be repeated with children who ride a bus to school. They can be asked to observe and discuss their observations of other buses appearing to move when they are moving. But there are other appropriate activities. We propose several activities built around the students drawing two-dimensional representations of three-dimensional objects. This could be as simple as having small groups of children seated around a table drawing their own view and the other students' views of three objects on the table without leaving their seat. They could also draw what they would see if they were looking at the objects from the ceiling. Comparing drawings, and the need to rotate some of the drawings to see the correspondence between the drawings, is a beginning activity for looking at diagrams of the earth, moon, and sun. Other examples of visual thinking activities are available at several websites, (Annenberg CPB Channel, 1999; Harvard-Smithsonian Center for Astrophysics, 1999; US Naval Observatory, 1999).

Relative size and distance.

The diagram provided by Moseley (1919) provides a wonderful opportunity to have children draw a variety of objects in and around their home and school showing relative size and distance. Integrating relative size and distance with relative position, children could draw a variety of pictures of activities such as ball games, from different perspectives and distances. This is especially convenient where professional sports show the field of play from different angles including those from the sky.

The shape of lunar and terrestrial shadows.

Shadows are clearly a problem when it comes to phases of the moon. While Engerstrom (1991) believes that some children's ideas for shadow causing the phases comes from eclipses, the fact that may children and adults maintain this idea about the phases should alert us to the fact that teachers and students need more experiences with shadows. The example of the shadows produced by different sized earths and suns (Olmsted, 1866) provides a starting point for many activities on shadows. Children can experience the kinds of shadows different shaped objects and different sources of light cast on spheres. This could lead to the question of how can you tell that the shape of the moon is caused as part of its normal cycle or is occurring as a result of an eclipse. For examples of the shadows on the moon during an eclipse see Card 115, in the Junior Secondary Science Project (1968-69).

Measuring schoolyard shadows of objects and children at different times of the day is one possibility. Shadow tag, catching others shadow, is another. Shadow activities can be a regular part of art and drawing activities included with relative position and relative size and distance.

The moon reflects light.

The evidence supporting the concept that the moon reflects light is critical in understanding phases of the moon. We are surprised at how simple the evidence is and wonder why it is never used. In addition to Ferguson's (1817) example of how we know the moon reflects light, Worchester, (1831), expands the idea to the earth when he says, "The moon reflects the sun and so does the earth. Earth reflects to the moon and other planets." This opens up a wide range of activities about reflections, a conceptual problem for primary school children. Students who use mirrors to reflect light, often think the light comes from the mirror. If mirrors reflect because they are shiny, how can rocks reflect? As with the other activities listed above, this activity can be related to young children's art activities. Reflections and shadows can be integrated in many primary school activities.

Hands-on experiences.

There are many hands-on activities related to phases of the moon. Using a "small ivory globe" or any other small round object the phases can be displayed inside a classroom with artificial light. It can also be tried outside using the sun as the source of light. This is a little problematic since the sun is above the horizon, creating an orbit for the "moon" that is not horizontal. A non-horizontal orbit is appropriate for reinforcing relative position and the idea that up and down, north and south, and east and west are relative directions in astronomy. There are many examples of hands-on activities in this area, including journal keeping by children and teachers, (Abell, 1998; Moore 1994; Website for the Harvard-Smithsonian program Looking at Learning Again, 1999)

The orbit of the moon around the sun was clearly a concept that Mattison (1872), NRF (1974), Proctor, (1878), and Smith, (1875) thought was worth describing. Currently, with all the visuals available on space, it is a topic worth considering as one of the concepts related to phases of the moon. It will allow a teacher to integrate the previous activities on relative position, relative size, and relative distance. And most importantly it relates to our conception of the names of the phases as indicated in the next section.

As teachers we may know and understand that the traditional diagram is just one representation of phases of the moon. But students, inexperienced at connecting different parts of school instruction, (Engerstr~m, 1991), may not tie in the earth's orbit around the sun to phases of the moon.

Names and length of each of the phases.

The idea that there are specific phases and they last for a while rather than the continuous motion of the earth, moon, sun system creating ever-changing phases, has not been touched in our discussions. It is a problem that we believe comes from listening to children and adults talk about the "specific" phases as if they last for several days. It is a topic that we think can be discovered and brought to light when studying the motion of the moon around the sun. When one considers the orbit of the moon around the sun, it is difficult to see the earth and moon as static or moving in bursts from one location and phase to another. Rather, the continuous motion, the continuous changing of phases, and the instantaneous nature of any phase becomes clearer.

This topic provides a good example of the complexity of determining what information needs to be integrated to complete an understanding of the phases of the moon, and how difficult it is to explain the observations clearly. On the one hand, the moon does not move from one specific phase to another. While it goes through a continuous transition, there are a few specific, although instantaneous phases, such as new, full, and first and third quarter. The problem is that we cannot see the slight differences between the phases. The moon looks "full" for a few days. On the other hand, the waxing and waning moon between the four phases named above are clearly changing continuously and last for several days. While the term waning is easy to understand since the shape is getting smaller, we rarely define these terms. We believe waxing comes from the analogy to making candles by repeatedly dipping a string into wax, and watching it increase slowly in size. Finally, throughout this paper we have talked of the phases of the moon. Possibly we should use the term "cycle of the moon." Historians cite the cycles of the sun and moon as providing human cultures with concepts of time, cycles, and seasons (Ferris, 1988).

Shape of the earth

The shape of the earth may be the most common piece of information we take for granted and assume children and most adults accept and understand. With all the photos of the earth from space and the entertainment industry's films about space travel, who does not understand the spherical shape of the earth? Yet there are many children who do not conceptualise the shape of the earth. More importantly, not many people can provide evidence or explanations for the shape of the earth. It is a very basic topic and one worth having children study. We will provide two sets of explanations from the beginning and end of the 19~ Century.

Bingham, (1805), wrote in a question and answer format common among books of that period. He asks, "What reafon do you have to fuppofe the earth is round?" The answers are, "1. This lhape is belt adapted to motion. 2. From the appearance of its lhadow in eclipfes of the moon. 3. From analogy: all other planets being round. 4. From its having been circumnavigated many times." (Script in the original)

Jackson (1894), also uses a question and answer format. His answers to the same question about the shape of the earth start with an analogy to a common observation. 'The same cause that makes the raindrop spherical, viz., *the mutual attraction of its particles."* He then goes on to discuss the attraction of gravitation. He states, "Every one knows that drops of rain are produced by invisible particles of cloud or vapor running together." According to Jackson it is precisely the same with the earth and other heavenly bodies. He then provides five proofs. The first is that, "the curvature of its surface may actually be seen." More importantly, "This convexity is found to be the same for the same distance, which could not be the case except upon a spherical body." Jackson then goes on to discuss methods for measuring the elevation of a middle target of three set up in a line. This might be an interesting activity to work out in class. It is also interesting to look at how we know that the curvature "proves" a spherical earth. Could the earth have a different shape?

His second proof is circumnavigation. The third is the fact that "The Horizon seems both to enlarge and sink as we ascend above the surface; whereas, if the earth were an extended plain, our field of view would not change whatever our elevation. The horizon is always circular, which would not be the case if the earth's form differed very much from that of a sphere." He then goes on to propose a demonstration to prove his example. "Cut a small circular hole in a card, and place it upon different parts of a globe. Suppose an observer to stand in the very centre of the aperture, in each position, the circle around him represents the horizon. If some other object be taken to represent the earth, as a cube or a cylinder, it will be seen that the hole in the card must be of a different form in order to fit different parts of its surface." His interest in knowing not only that there is a curvature, but that is it the same over the entire earth, opens up lots of activities relating to mathematics, social studies, and as always, art.

As described earlier in this paper, Jackson raised the issue as to whether these explanations were solid. He then provides what he thinks are more direct proofs. *"The Weight of a Body* is very nearly the same at all parts of the earth's surface, which could not be the case if the earth were not nearly spherical, since the same body grows heavier the nearer it approaches (on the surface) the center of the earth." His final proof is based on the observation that during eclipses the earth's shadow is always circular. We have no idea why these several examples ignore explanations from the Greeks, both the change in position of the stars as you move north and south and the measurement of the size of the earth using the sun's shadow.

In considering the shape of the earth, we also want to bring up the importance of distinguishing the artificial globe from the spherical earth. When children talk about the shape of the earth they often explain that the round earth is up in the sky, or only seen from rocket ships (Nussbaum, 1979). As with so many of our other basic concepts related to phases of the moon, it is easy to understand that adults would rarely think that children can confuse such commonly accepted examples and ideas.

The phases from the different hemispheres

It is critical in the study of phases of the moon, and other science topics, to focus on the entire earth. From weather and climate to seasons and gravity, it is critical to make sure the perspectives from both hemispheres are included. The idea of relative position created by viewing objects from other places can reinforce spatial concepts. Even Leonardo di Vinci raised the issue of looking at the earth from the moon, shortly after Columbus made his famous voyage in 1492 (Ferris, 1988). Ginns (1993), authored one of the few articles written to help teachers explain phases of the moon that includes both Northern and Southern Hemisphere views.

Summary

In this paper we have looked at the teaching of a common school science topic over hundreds of years and found little difference between the current basic ideas and those from 1756. However, it appears that in the past more effort was devoted to carefully explaining the background and underlying concepts behind the topic. Fewer concepts, such as the shape of the earth and the causes of shadows, were taken for granted.

We believe that we have shown that even a basic science topic, such as phases of the moon, involves a complex set of concepts and that these concepts require a sophisticated understanding on the part of the teacher of both the science and how children learn that science. We are concerned that the content of university introductory course seems to determine the content of elementary and secondary schools. Referring once again to the 19th century, we find Bert (1878) discussing the late 19 century French attempt to obtain 'good elementary text-books for schools." Bert quotes Lakanal as saying, "To cut down, to compress the substance of a large book, that is what I call abridgement. But a good elementary work is one which presents the seeds or germs of knowledge, one whose light is the dawning of the full day of scientific thought."' He continues "'An abridgement, then, is exactly the opposite of an elementary treatise."' In this paper we have attempted to define the "germs of knowledge" basic to phases of the moon. We believe integrating information from old textbooks with children's concepts is consistent with current ideas of science education such as the teacher as researcher, the integration of science with other areas, and the idea that we can teach more by teaching less. In short, this paper is consistent with a constructivist approach by providing a wide variety of activities for school children from which they can develop a clearer and more personal understanding of the phases of the moon.

We also think this paper raises several questions. How much does a teacher need to know to be able to effectively teach a topic? Do children have to learn all the concepts a teacher understands and thinks are relevant to the topic? What is the best sequence for teaching the many topics related to phases of the moon? And how do these expanded views of the concepts related to phases of the moon change our educational research?

Footnotes

1. The authors, in a review paper such as this, appreciate the perspective of the philosopher of science Morris R. Cohen who said, "The notion that we can dismiss the views of all previous thinkers surely leaves no basis for the hope our own work will prove of value to others," (Cohen, 1931). We have therefore not cited authors who might be embarrassed by critical comments, as we are aware that many authors have little control over the artwork included in their books. Others use material from texts and articles that they assume are accurate.

2. James Ferguson lived from 1710 to 1776. According to Ferris (1988), Ferguson began to study astronomy as an uneducated shepherd. He taught himself to read, became a teacher, and wrote two popular astronomy books. We have used parts of these two books in this paper. His books had many editions, with several published in the United States well after Ferguson died.

3. This is another example where we do not want to embarrass the author for a case of mis-judgement.

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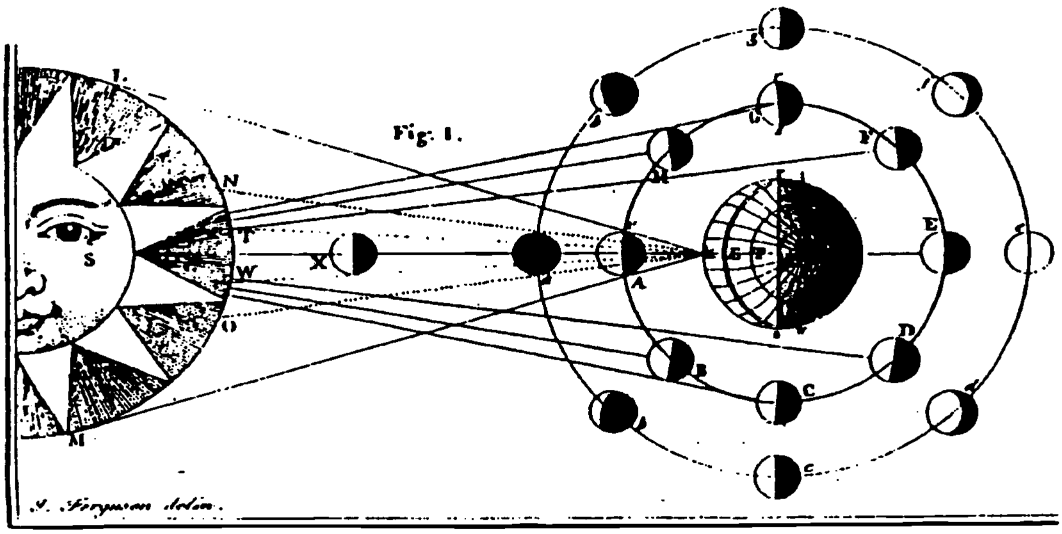
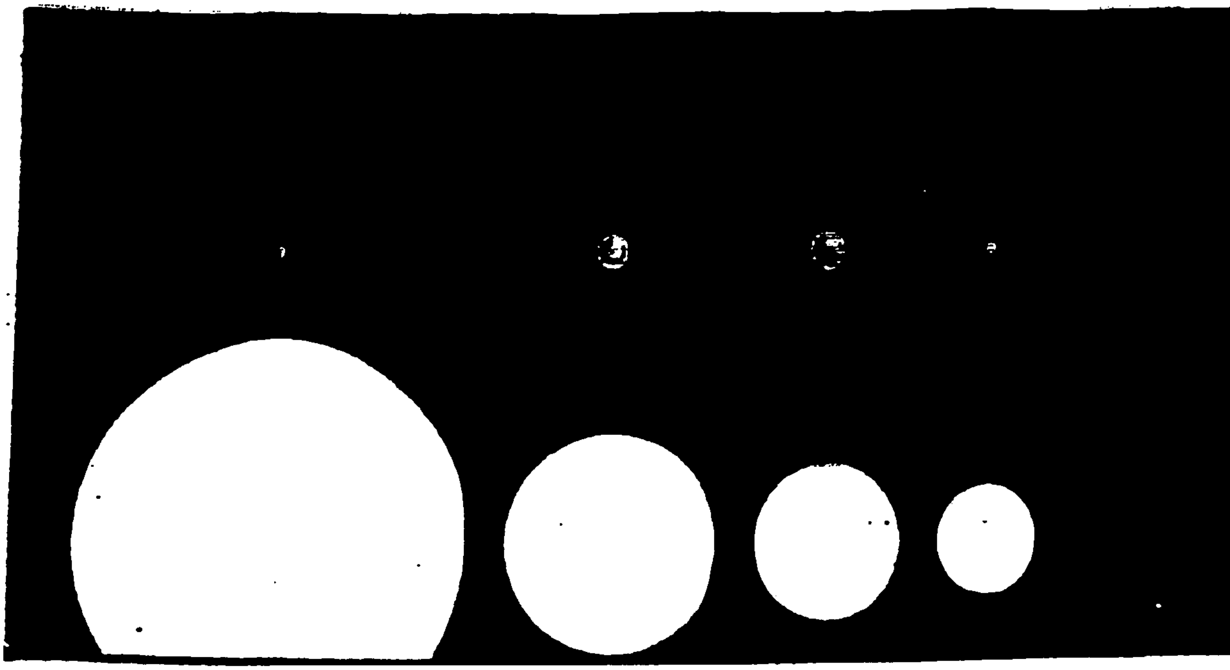


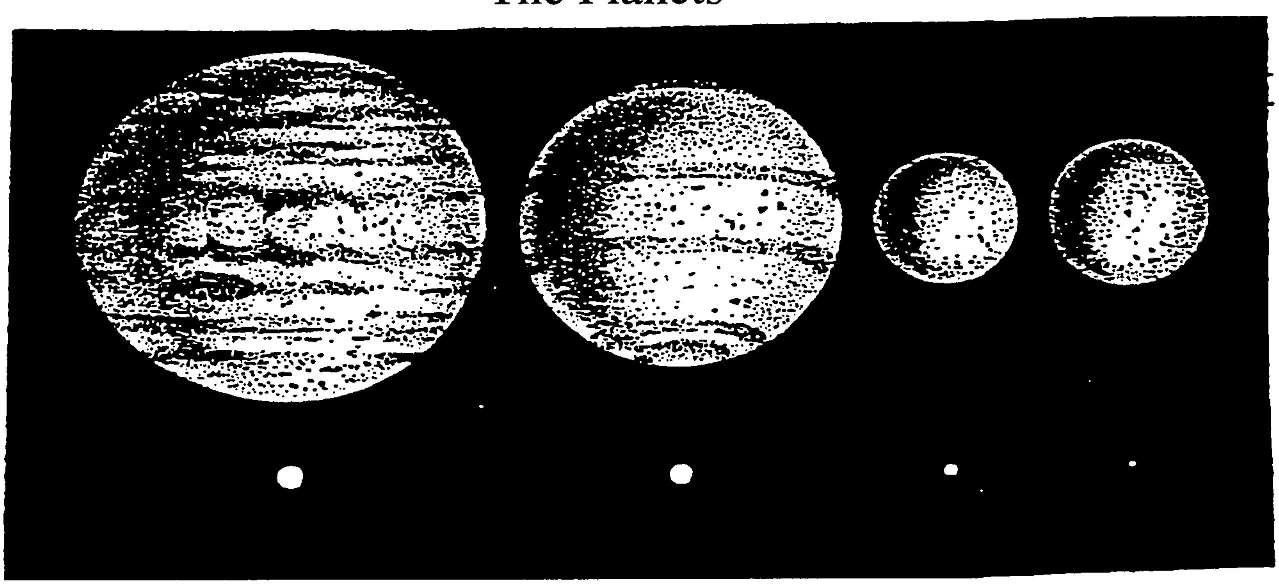
Figure 1. Figure 1 of Plate VIII in Ferguson (1756) depicting the phases of the moon diagram similar to those used today.

234 Trees, Stars, and Birds



FIGS. 141 and ***142.*** The upper row shows the relative sizes of the planets, the

The Planets



235

lower row the comparative sizes of the sun as viewed from each of the planets.

Figure 2. Figures 141 and 142 in Moseley, (1919) showing the relative sizes of the planets and the comparative sizes of the sun as seen from the planets. Note there are only eight planets because Pluto had not been discovered.

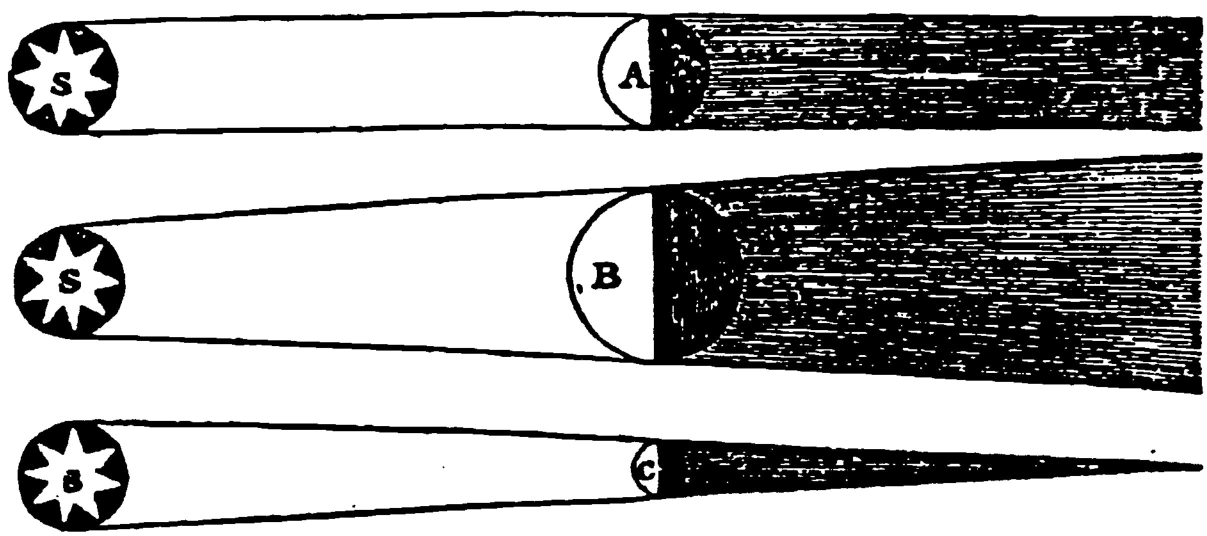


Figure 3. Olmstead (1866) showing the how variations in the sizes of the earth and sun change the shape of the shadow of the earth.

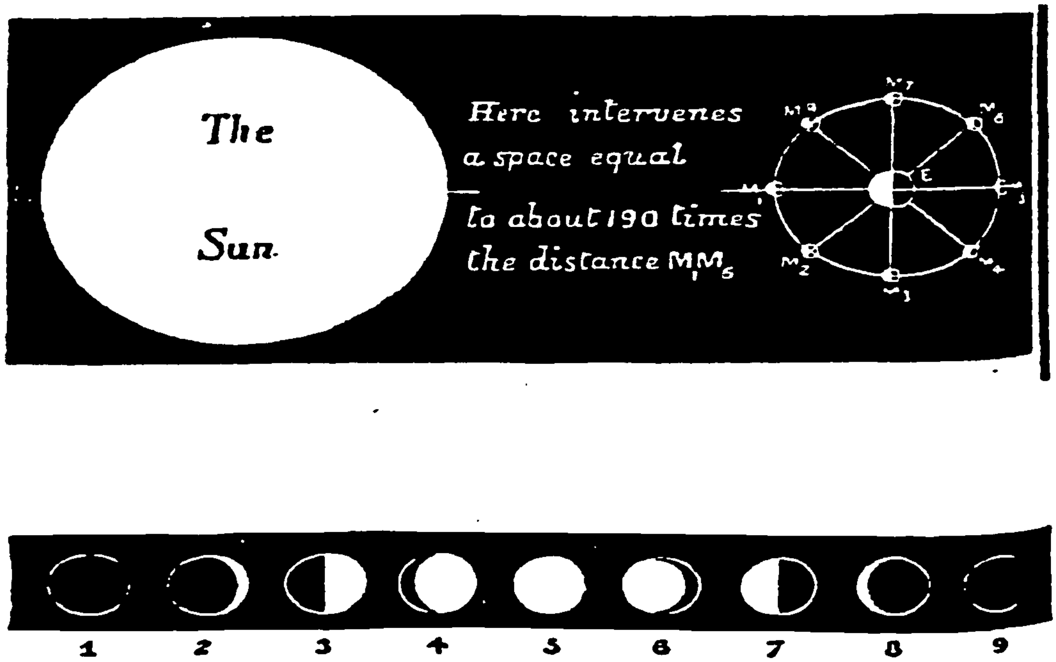


Figure 4. The diagram of phases of the moon from Proctor ((1878). His diagram is divided into sections, one representing the view from space and the other the view from earth. He adds, "The earth and moon are relatively much exaggerated in dimensions; and the moon is shown in eight equidistant positions, as though she performed a complete circuit while the earth remained at E."

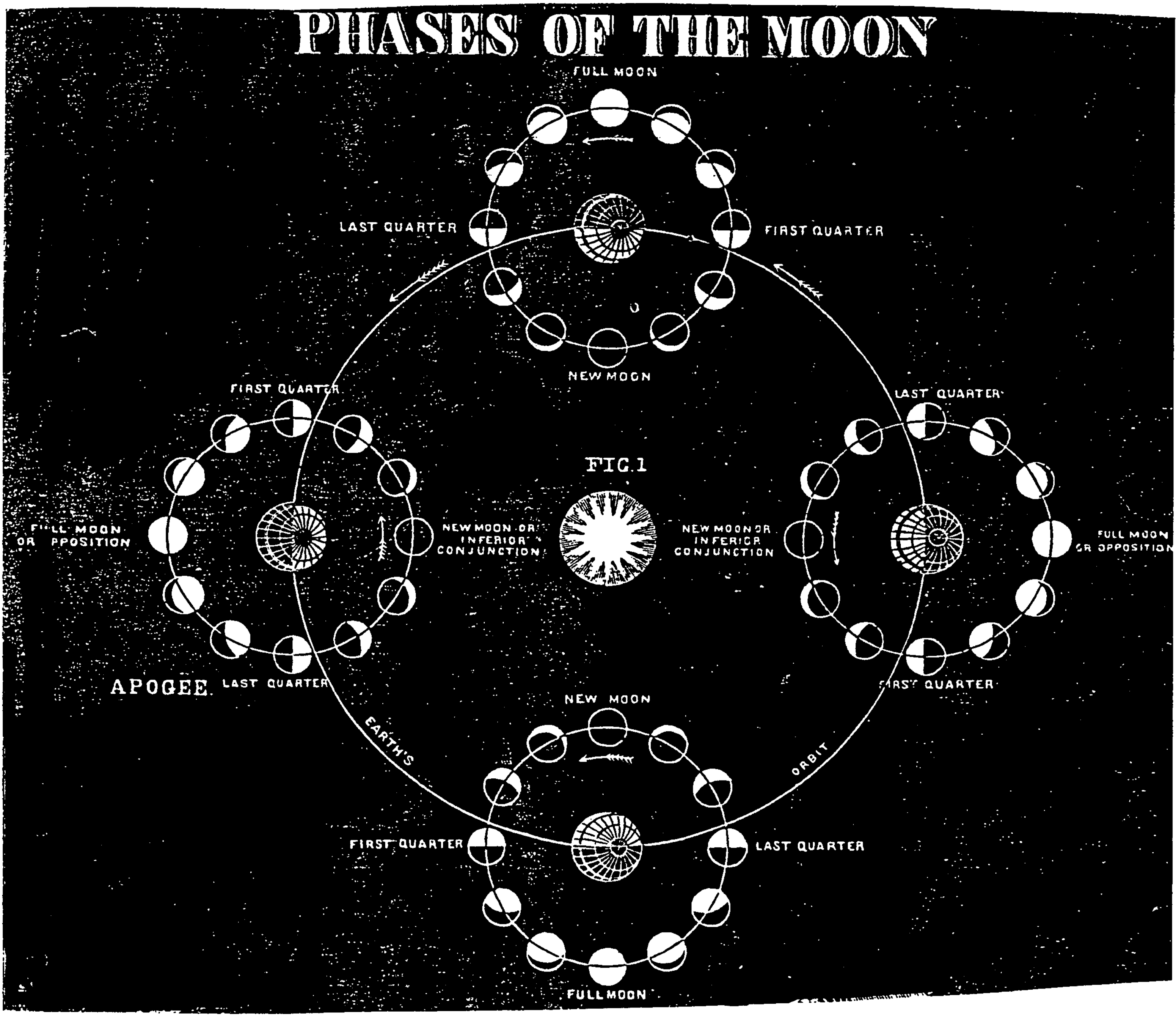


Figure 5. A view of the phases of the moon at four different positions within the earth's orbit (Smith, 1875).

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