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Do Elementary Science Methods Textbooks Promote Understanding of Shadows?

Lloyd H. Barrow [*]
University of Missouri, Columbia

Abstract

Elementary science methods textbooks can be an important resource for future elementary teachers of science. Since shadows are a common topic in elementary school and Next Generation Science Standards (NGSS Lead States, 2013). A series of ten shadows concepts were formed into a learning progression by Wizman and Fortus (2007). For this research, ten science methods textbook were read and analyzed about how each of the shadow concepts were addressed. These methods textbooks focused on a limited number of shadow concepts. Consequently, as a future reference, they are very limited in addressing all ten shadow concepts.

Keywords*: science concept, shadows, methods textbooks, learning progression*

[*] Lloyd H. Barrow, Missouri Science Education Center, University of Missouri, Columbia, USA Correspondence: Lloyd H. Barrow 5012 Cullen Court, Columbia, MO 65203, USA Tel: 1-573-443-0910.,
E-mail: *barrowl@missouri.edu*

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Introducing the Problem

Observing and producing shadows is one of the favorite physical science topics of elementary children. The *Frameworks for K-12 Science* (National Research Council [NRC] 2011) has a fourth area – waves, which is a new category for many K-6 science teachers. *Next Generation Science Standards* (NGSS) notes that "objects can only be seen when light is available to illuminate them" (K-2) and "An object can be seen when light reflected from its surface enters one's eyes." (3-5)(NGSS Lead States, 2013, p. 42) However, waves were not included in the *National Science Education Standards* (NSES, NRC, 1996) and the Benchmarks for Scientific Literacy (American Association for the Advancement of Science [AAAS], 1993). The study of shadows helps students to begin their conceptual development about light and waves. Some elementary children are fascinated with shadows and others are scared of some shadows. Children can observe the shadow of the school's flagpole and notice how it changes during the day. This can be done by marking the length and the position of the shadows in the morning, noon and afternoon. The multiple day observation allows elementary students to observe the position is different from one day to another. However, observing shadows does not mean elementary students understand how a shadow is formed and seen.

Theoretical Framework

This research study utilized both conceptual learning and learning progressions as the theoretical framework. Conceptual learning is the process where new knowledge is being incorporated into individuals' understanding (Maclellan, et al., 2005). Scott, Asoka, and Leach (2007) identified three fundamental aspects of conceptual learning: an individual's belief about the natural world are personally constructed, different individuals have commonalities in what they think about the natural world, and individual's prior knowledge of the natural world greatly influences about what they will learn.

Because elementary teachers have a limited science background, especially physical science (Weiss, 1987), their science methods textbook can be valuable in the future teaching. All future elementary teachers have observed shadows, however, do they understand about how shadows are formed and seen? Future teachers frequently will have misconceptions about shadows that can serve as a barrier to their future students learning accurate shadow concepts.

Related Literature

The nature of a shadow is due to an object blocking light rather than a scientific description that light rays travel until they hit something. Fehr and Rice's (1988) noted students' alternative concept that a shadow is something considered to be alive, black stuff, and substance rather than the absence of light. Neal, Smith and Johnson (1990) reported that elementary students don't connect shadows with a light source. Some students consider shadows are pushed out by the light. In addition, the size of the shadow is based upon the size of the object. Earlier, Piaget (1930) reported children considered a shadow as something concrete that was projected from the body. Piaget also reported that 8 to 9 year olds correctly predicted that the shadow will be on the opposite side from the light source, but did not understand cause-and-effect relationship between the shadow and light source. While, Chen (2009) reported children have a more sophisticated understanding about shadows (size, shape and production) than Piaget reported. Eschach (2003) identified elementary students' incomplete understanding about diffused shadows. These included that shadows exist independent of light sources and could come from a projection of a person, animal, or object. Others thought it was necessary for light to be present before a shadow could be seen (shadows are always present). Also, others believe reflected light or clouds are necessary to create shadows. Some students assigned human attributes to shadows; especially scary ones.

Students' preconceptions about shadows come from their everyday personal experiences; even though, these experiences vary from student to student. Teachers should be aware that these preconceptions can put learning constraints on students developing understanding about forming shadows. If a teacher of science doesn't address these pre-conceptions directly, elementary students will resort to memorization of what happens in science class, but still utilize their experience – based preconceptions in their everyday world (Donovan & Bransford, 2005). Teachers need to remember that students' everyday experiences make sense them in determining what to trust; everyday experiences or school science. Magnuson and Palincsar (2005) includes numerous experiences students have had with light, shadows, and darkness that teachers should not ignore.

According to Wizman and Fortus (2007), elementary students must understand the nature of vision before they can fully understand the nature of shadows. They identified 10 sequential concepts

that are required to have a full understanding about shadows formation and their observation. This learning progression was designed to be completed by the end of sixth grade. The concepts are:

1. Light travels in straight lines;
2. Light hits an object (barrier) and bounces in another direction;
3. A shadow is created by light and not something material;
4. We see the light around the shadow, not the shadow;
5. A scene shadow begins right from the objects (attached to it);
6. Shadows position depends upon the position of the light source;
7. Shape of the shadow depends upon the shape of the object;
8. Shadow's size depends on its distance from the light source;
9. We see by detecting light that enters our eyes; and
10. We only see a shadow when all four conditions exist: light source, eyes, object and a straight unblocked path.

Wizman and Fortus considered the development of being able to see shadows (the nature of vision) a more advanced conceptual knowledge than the nature of shadows. "Students need to understand first that a shadow is related to light and created by an object blocking the light, in order to understand we see only light around the shadows" (p. 18). Their learning progression is different from Magnuson and Palincsar (2005) who focused upon what happens when light interacts with materials – reflects, passes through or blocked (thereby creating a shadow).

The purpose of this study was to determine which shadow concepts of Wizman and Fortus' learning progression are found in various elementary science methods textbooks, and how these resources could clarify future teachers understanding and misconceptions about shadows.

Procedures

The table of contents and indexes of elementary science textbooks were searched for keywords such as shadows, light, waves etc. If an elementary science methods textbook did not have these keywords they were excluded. Each of the methods textbooks were read in detail to ascertain how shadows and related aspects were presented. A detailed analysis (Wizman & Fortus, 2007) for each concept of each method book was completed. When a concept was presented with an investigation/activity it was noted. The diversity of format/presentation in each methods textbooks is described in the subsequent paragraphs of where shadow concepts are described.

Methods Textbooks Used in Study

Martin, sixth edition, (2012) provides a brief description of one activity to help students observed that the angle of the light source influences the shadows length. Shadows section is matched to the *NSES* (1996) physical science content standard. Stevenson's poem "My shadow" is recommended to assist students in developing the concept. Also, additional literature connections are provided with brief summary. Concepts related to light are found in various locations in this method textbook. For example, the area illuminated when held at different angles and comparison of the speed of sound with the speed of light.

Buxton and Provenzo, second edition, (2011) provides background information about sundials and how they can be used for identifying shadows, plus an experiment where students investigate shadows changes during the day. This outside activity has students compare the length of the shadow cast at each time of the day to the actual height of the meter stick. Students are encouraged to repeat the investigation at different seasons and different months. Questions relate back to how sundials tell time. *NSES* (1996), mathematics, language arts, and social studies standards are identified. The shadow activity is found in the light and color section which includes discussion of persistence of vision, color blending, and bending light.

Bass, Constant and Carin (2008) focus upon how light interacts with transparent, translucent and opaque materials. This method textbook encourages the *NSES* model (1996), but fails to give explicit example. A single shadow activity utilizes a shadow theatre. Shadows are produced when an opaque object blocks light. A series of questions (e.g. changing shadow size) encourages students to figure out how shadows are formed. A subsequent activity investigates whether light travels in straight or curved lines. However, no connection to shadows was made. They will have a 12th edition published in 2016.

Howe, third edition, (2002) encourages children to make outdoor observations at midmorning or midafternoon of shadows. Teachers are encouraged to provide an explanation to students that light from the sun does not pass through an object, thereby, creating a shadow. Students are directed to

compare their shadow's position in relation to other students. Children are asked how could they make their shadows touch when they weren't touching. Subsequent classroom activity could involve shadow puppets or using their hands to form animals. There is no section in this methods book on light.

Lorbeer, 11th edition (2000) in the section on light and color has a single activity entitled "what causes a shadow?" Detailed procedures and equipment are described. Objects to create shadow are moved to different positions to illustrate how this shadows size changes. Typical results and facts are provided for the teacher: shadow is only formed when an object is between the light source and the surface, shadows size decreases when an object is moved away from the light source, light travels in straight lines and light rays do not pass through objects. Three thought-provoking questions concerning changing the height of the shadow, making shadow a different size and how a sundial works are included.

Victor, Kellough, and Tai, 11th edition, (2008) section on shadows is within the astronomy chapter. Students are encouraged to conduct activities on shadows outside at different times of the day (early morning, noon and late afternoon). Older students can measure, record, and graph their height, shadow height, and direction the shadow is pointing at different times of the day. A series of questions are provided for the teacher to stimulate students understanding of the link between shadows and time. Sundials are also mentioned.

Lederman, Lederman, and Bell (2004) has a sequence of eight pages focusing on shadows. This section is part of the astronomy part of the methods textbook. Narrative description of using a shadows sticks to provide data at different times of the day for shadow length are the focus. Questions about when the shadow is the longest and shortest are utilized with a globe activity. A teaching scenario is provided where an elementary teacher has students making predictions and then testing their personal theory. This scenario, assessment, and reflection is dependent upon students being able to understand cardinal directions. They use a stick figure which showed that shadow was touching stick figure.

Tolman, third edition (2002) has concepts related to shadows at several locations throughout the book. Children are encouraged to compare shadows at the same time for different days to promote their curiosity. An operational definition about how an opaque object blocks the source of light, thereby, creating a shadow requires students to realize that light travels in straight lines. Both umbra and penumbra are identified. An investigation about how shadow patterns change at different times of the day includes students generating prediction about the length for a different time of the day. A second activity involved the construction of a shadow clock/sundial and checking its accuracy for several days. Concern about daylight savings time is mentioned to avoid confusion. Seasonal variations where shadows are longer in the winter was also mentioned.

Sunal and Sunal (2008) provides background and a series of questions that promotes students' understanding about shadows in their physical science section. They include:

Do shadows stay in one place?

What causes a shadow?

Predict the location of an object's shadow three hours later.

Why does a shadow move?

This resource extends to middle school However, there is no recommendation about grade placement. Like many of they textbooks, they utilize *NSES* (1996) and Benchmarks (AAAS, 1993) to help future teachers consider how to teach shadows.

Dobney, Beichner, and Jabot (2003) has a general methods orientation with a science emphasis. Shadow activities are in multiple locations. Topics are connected to *NSES* (1996) and AAAS (1993) using cooperative learning strategies.

Results

Table 1 has the results of the shadow's learning progression for each of the elementary science methods textbooks. All of these textbooks fail to provide even close to a majority of the concepts. The most common concept is the position of the shadow. This concept was found in all but two of the methods textbooks. Three of the concepts (light hits an object will bounce, light creates shadow, and light must reach our eye to be seen) were never mentioned in any of the textbooks. In addition, the reason why we see a shadow was never fully explained in any of the textbooks. Consequently, these resources are not an effective resource for future teachers in helping their students understand about shadow information.

Table 1. Summary of shadow concepts for methods textbooks

	Bass, Contant & Carin – 7th Ed (5E Model)	Martin – 4th Ed.	Buxton & Povenzo Jr.	Tolman	Lorbeer	Dobey, Beichner, & Jabot	Sunal & Sunal	Lederman, Lederman, & Bell	Victor, Kellough, & Tai	Howe
Light travels in straight lines				X	X	X				
Light hits an object and bounces in another direction										
A shadow is created by light not something material										
See the light around the shadow, not the shadow				X						
A shadow (attached to it)								X		
Shadow's position depends upon the position of the light source	X	X	X	X			X	X	X	X
Shape of the shadow depends upon the shape of the object										X
Shadow's size depends on its distance from the light source					X					
We see by detecting light that enters our eyes										
We only see a shadow when all four conditions are present: a) light source, b) eyes, c) object, and d) straight unblocked path	a, c				d	d			a, c	

Conclusions and Discussion

Overall, these elementary science methods textbooks are very inadequate in helping teachers in developing students' full understanding about shadows. The learning progression is a multiple year development. Therefore, teachers need an instructional model for lessons. Barrow (2012) uses three parts to help students to accurately construct their knowledge of shadows – prior knowledge, factual and conceptual knowledge, and metacognition – based upon Donovan and Bransford's (2005) model of *How People Learn*. Each subsequent grade could start by using something like "Me and my shadow" (Keiley, Eberle, & Dorsey, 2008).

The majority of these ten shadow concepts can be represented by a student investigation. For example, a student's drawing that does not have the shadow touching the object would need to be probed for student to compare their drawing with actual shadow. "Where does the shadow start? How does your drawing of a shadow compare with the shadow you made?" Some students might not have considered the starting position.

It is possible that some students will not develop an understanding of being able to see shadows that Wizman and Fortus (2007) calls "the nature of vision." They consider this to be more advanced than the "nature of shadows." Students need to understand first that a shadow is related to light and created by an object blocking the light and created by an object blocking the light, in order to understand we only see light around the shadows" (p. 18). Consequently, what we see as a shadow is an area where no light is bounced back to our eyes. In addition, a shadow is formed because light travels in straight lines.

There are several limitations to this study about how shadows are presented in elementary science methods textbooks. These results do not mean that the textbooks are inadequate/inappropriate except for the study of shadows. The vast majority of these textbooks had an activity orientation which is not as frequent in more recent elementary science methods textbooks. These textbooks do not have a learning progression approach by its absence in table of contents and index. The wave orientation of *NGSS* (2013) is not utilized in the science methods textbooks because most were published prior to *NGSS*. However, they could still be used in elementary science methods. For example, some put the shadows in the astronomy chapter.

Future study could investigate how various web sites address the learning progression of shadows. Are these websites more compatible with properties of waves of *NGSS* (2013)? A qualitative study could identify which of the ten concepts are more difficult for teachers and students.

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