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# Helping Students Construct Understanding about Shadows

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**Abstract**

The study of shadows is a common elementary science topic that facilitates students' development of understanding about light and associated waves. All elementary students have observed numerous shadows, but need assistance in developing understanding. Previous research studies about shadows were utilized in organizing aspects associated with shadows. This review paper encourages teachers to utilize three principles of learning: students' prior knowledge about shadows, factual and conceptual knowledge related to shadows, and metacognition requiring students to think about their personal understanding about shadows; thereby, promoting students' science literacy.

**Keywords:** elementary science, curriculum planning, prior knowledge, factual and conceptual knowledge, megacognition

## 1. Introduction

Shadows are something all children have seen. Some have played shadow tag; others have observed a sundial. They have observed their shadow leading them in their walk to school in the morning and leading them home in the afternoon. The fact that the length of the flag pole's shadow changes during the day has been frequently mentioned by children. How does an elementary teacher develop a unit on shadows? This review focuses upon resources to facilitate elementary teachers in their development of a shadow unit. The National Research Council's *How Students Learn* (Donovan & Bransford, 2005) identifies three principles of learning that teachers of science should utilize in all of their science units. They are: prior knowledge, factual and conceptual knowledge, and metacognition. Each of these parts will be addressed in helping students to accurately construct knowledge about shadows.

## 2. Prior Knowledge

The first principle "Engaging prior knowledge" is essential in planning your shadow unit. Observing shadows is a science topic that all students have practiced. However, observing doesn't equal understanding about how shadows are formed. Students frequently will have misconceptions, also called alternative conceptions, pre-conceptions, naïve knowledge, etc. (Wandersee, Mintzes, & Novak, 1994). These misconceptions can serve as barriers to a child learning the accurate shadow concepts. There are several ways an elementary teacher of science can assess their students. For example, have the students draw where the sun would be located to form a shadow on the playground (Barrow, 2007). Another approach would be to have students list everything they know about shadows. This would become the first column of a K-W-L chart (Ogle, 1986). A review of these statements allows identification of students' accurate concepts and misconceptions about shadows. Working in small groups will allow students to share experiences plus realization that not everybody has the same shadow experiences. Sometimes in planning for the shadow unit, elementary teachers will frequently locate related literature to enrich their study of shadows. These could include Robert Louis Stevenson poem, songs such as "Me and my Shadow," and "I'm Being Followed by a Moon Shadow." Students will sometimes volunteer that TV cartoon Scooby-Doo gets scared of his shadow. Keeley, Eberle, & Dorsey (2008) used an earlier version of this paper in developing a shadow's formative assessment.

Part of your planning needs to include what research has identified as common student misconceptions. The nature of a shadow is due to an object blocking light rather than the scientific description that light rays travel until they hit something. A frequent common misconception is Feher and Rice's (1988) alternative concept that a shadow is something considered to be alive, black stuff, and of substance, rather than the absence of light. Earlier, Piaget (1930/2001) reported children considered a shadow as something concrete that was projected from the body.

Neal, Smith and Johnson (1990) reported that some students don't connect shadows with a light source. Other students consider a shadow is pushed out by the light. In addition, the size of the shadow is based upon the size of the object. Piaget (1930/2001) reported that 8-9 year olds correctly predicted that the shadow will be on the opposite side from the light source, but did not understand the cause and effect relationship between the shadow and the light source.

Students' preconceptions about shadows come from their everyday personal experiences; even though, these experiences may vary from student to student. These preconceptions, based upon their experiences, can put learning constraints on students' development of an understanding about shadows. Students have had numerous experiences with light, shadows, and darkness (Magnuson & Palincsar, 2005) which teachers should not ignore. If a teacher of science doesn't address these preconceptions directly, students 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 to them in determining what to trust: everyday experiences or school science.

## 3. Factual and Conceptual Knowledge

The second principle is "Essential Role of Factual Knowledge and Conceptual Framework" (Donovan & Bransford, 2005). Factual knowledge must be placed in a conceptual framework to be understood which requires multiple science experiences to be understood. Students need to have both factual and conceptual experiences to develop a full understanding about shadows. Conceptual knowledge helps students to connect individual facts in an organized way; thereby, giving additional meaning to their factual information.

This second principle provides opportunities for students to conduct a series of investigations involving shadows. The key aspect of student investigation is a testable question (National Research Council, 2000, 2012). Until the publication of the *Frameworks for K-12 Science Education* (NRC, 2012), the focus was to be scientific inquiry. However, understanding of what is inquiry (Barrow, 2006) resulted in NRC replacing the term "inquiry" with the term "scientific and engineering practices (NRC, 2012). There are eight components of practices including:

1) Asking questions

2) Developing and using models

3) Planning and carrying out investigations

4) Analyzing and interpreting data

5) Using mathematics and computational thinking

6) Constructing explanations

7) Engaging in argument from evidence

8) Obtaining, evaluating, and communicating information

Bybee (2011) provides detailed explanation of the evolution from process of science (emphasis on post-Sputnik era) to inquiry and now practices. The study of shadows in the *Next Generation Science Standards* (Achieve, 2012) helps elementary students start to build understanding about light before their study of waves in Grade 5.

Magnusson and Palincsar (2005) provided detailed descriptions of their fourth grade light unit. A critical aspect in preparing your investigations begins with a general question "How are shadows formed?" Specific questions formulated to help students study about shadows could include:

When is the shadow the shortest?

When is the shadow the longest?

How does your morning, noon, and afternoon shadow compare?

How do you change the size of your shadow? Make it longer? Bigger? Shorter?

In completing the second column of the K-W-L chart, students will share their personal questions that can form additional investigations. Bishop and Barrow (1998) contains additional interdisciplinary learning center topics regarding shadows. A teacher would need to determine whether it would be best to address the students' questions in a particular sequence or randomly. Students' misconceptions about shadows could influence this decision. It is imperative that teachers continually check students' developing conceptual knowledge about shadows. When students share their results, they provide teachers with additional information to be used to facilitate children's developing conceptual knowledge. This sharing can be in small groups or whole groups. It also helps students to connect factual knowledge about the interaction action of the light source and object resulting in various size and location of shadows. Students' drawing will allows teachers to see the model that students have as a mental model.

Magnusson and Palincsar (2005) encouraged the use of second-hand sources (e.g., peers' science notebook entries, textbooks, information trade books, websites, etc.) to build upon what they call first-hand inquiry investigations. They encouraged scientific entries of observations made of various shadows in science notebooks. The teacher must build the connection between first-hand results and second-hand information. Otherwise, students will not develop fully conceptual knowledge and continue to utilize their preconceptions when interacting with shadows. Your shadow unit must include multiple student investigations to build a rich conceptual understanding of organized factual knowledge.

## 4. Metacognition or Self-monitoring

The third principle "metacognition" focuses upon where students are to take greater control and monitoring their learning (Donovan & Bransford, 2005). Students need to develop an awareness of how their new knowledge about shadows alters their existing knowledge. While working in groups, students will share their preconceptions and how the investigations influenced their emerging conceptual knowledge. Sometimes, this discussion will result in further questions to be investigated such as 'Does a colored light source make the same type of shadows?' Teachers can facilitate metacognition by probing students to identify the evidence they are using when reporting their findings (Donovan & Bransford, 2005).

To illustrate metacognition, have students draw how they can see their own shadow. To be able to represent this concept requires the understanding of vision. According to Weizman and Fortus (2007), students must understand the nature of vision before they can fully understand the nature of shadows. They identified the following concepts regarding shadows for sixth graders:

1) Light travels in straight lines;

2) Light hits an object and bounces in another direction;

3) A shadow is created by light not something material;

4) We see the light around the shadow not the shadow;

5) A shadow seen begins right from the object (attached to it);

6) Shadow's position depends on 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 occur: light source, eyes, object, and straight unblocked path.

Weizman and Fortus consider the development of being able to see shadows (nature of vision) 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 that we see only light around the shadow" (p.18). Teachers can form a rubric for these ten concepts to determine students' level of understanding about shadows. Weizman and Fortus had a greater depth of conceptual knowledge of shadows than Magnusson and Palincsar (2005) who focused upon what happens when light interacts with materials. Magnusson and Palincsar considered there were three options: reflects, passes through, or blocked.

## 5. Conclusions

To be able to plan a shadow unit that will result in depth of conceptual knowledge, teachers must have sufficient subject matter knowledge about shadows. The ten concepts identified by Weizman and Fortus (2007) illustrate the multiple concepts needed to understand about shadows and their formation. It is inappropriate to expect all students to have a full understanding about shadows. The study of waves in Grade 5 (Achieve, 2012) where the focus is upon light travels in straight lines is so students will be able to understand how shadows are formed. However, both the *National Science Education Standards* (National Research Council, 1996) and 2009 National Assessment of Educational Progress Science Framework (2007) identify that K-4 students understand light travels in a straight line. Research reported here does not concur. In addition, students must understand how the eye sees things like when light around the shadow is reflected to the eye. The shadow's unit requires teachers to plan their lessons which involve prior knowledge, factual and conceptual knowledge and metacognition.

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