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Using the Learning Cycle as a Model for Teaching the Learning Cycle to Preservice Elementary Teachers

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Abstract

The learning cycle has been embraced as a teaching approach that is consistent with the goals of the National Science Education Standards *(National Research Council, 1996). Science teacher educators may be disappointed to find, however, that preservice teachers may fail to grasp this model, even after extensive instruction (e.g., Settlage, 2000). Our own preservice teachers often express the belief that teaching multiple activities related to a single concept is redundant. In this manner, they fail to grasp the importance of carefully sequencing learning activities to promote conceptual development. In this paper, we describe an approach in which we use the learning cycle as a model for our own instruction to assist preservice elementary teachers in developing "conceptual storylines" through carefully sequenced activities that follow the learning cycle.*

Introduction

The learning cycle was developed in the 1960s by Karplus and Thier (1967) for the *Science Curriculum Improvement Study* (*SCIS*). This inquiry-based teaching approach is based on three distinct phases of instruction: (1) the *exploration,* which provides students with firsthand experiences with science phenomena; (2) the *concept introduction*, which allows students to build understanding of science concepts through interaction with peers, texts, and teachers; and (3) the *concept application*, which requires students to apply their understanding to new situations or new problems. Since Karplus and Thier introduced the learning cycle, several different models, including different numbers of phases, have been proposed; however, regardless of the number of phases they include, "each new version retains the essence of the original learning cycle—exploration before concept introduction" (Brown & Abell, in press). A popular version of the learning cycle is the 5E Model: Engagement, Exploration, Explanation, Elaboration, and Evaluation (Bybee, 1997). It incorporates the three original learning cycle phases while adding two more. At the beginning of the cycle, the Engagement phase is an opportunity for the teacher to hook students' attention and uncover their prior knowledge about the concept(s). While listed as the fifth phase, the Evaluation phase is typically embedded throughout the cycle, providing opportunities to assess students' progress both formatively and summatively.

There has been a great deal of research concerning the learning cycle since its origins. Much of the research supporting the learning cycle is discussed in detail in Lawson, Abraham, and Renner (1989), which supports the conclusion that the learning cycle can result in greater achievement in science, better retention of concepts, improved attitudes toward science and science learning, improved reasoning ability, and superior process skills than would be the case with traditional instructional approaches (e.g., see Abraham & Renner, 1986; Beeth & Hewson, 1999; Gerber, Cavallo, & Marek, 2001; McComas, 1992). As a model for planning instruction, the learning cycle "can help teachers 'package' important instructional goals into a developing conceptual 'storyline' that accommodates both selection and sequencing of learning opportunities" (Ramsey, 1993, p. 1). In doing so, teachers can avoid the use of episodic and fragmented instructional activities or "activitymania" (Moscovici, 1998).

Figure 1. Template for Debriefing Learning Cycle Lesson ***(Emphases indicated are for instructor purposes and are adapted from Abell & Volkmann, 2006)***

The Learning Cycle

Phase of Instruction	Activities of the Teacher	Activities of the Students
Engagement	• Establish a context for study. • Motivate students. • Identify students' current science ideas and misconceptions. • Figure out what students need to explore in the next phase.	• Connect past and present learning experiences. • Start thinking about concept to be explored. • Get motivated and interested.
Exploration	• Provide a common set of experiences for students. • Determine how students are processing in their conceptual understanding. • Determine what students need explained in the next phase.	• Clarify and test their ideas against new experiences. • Compare their ideas with ideas of their peers and the teacher.
Explanation	• Provide opportunities for students to use previous experiences to begin making conceptual sense of prior explorations. • Introduce formal language, scientific terms, and content information as needed. • Determine what concepts need further instructional attention. • Determine what elaborations will help scaffold learning in the next phase.	• Demonstrate their current understandings. • Develop explanations based on prior experiences. • Use formal language, scientific terms, and content information to aid them in describing and explaining.
Elaboration	• Provide opportunities to apply or extend the students' developing ideas through new activities. • Assess how students use formal representations of science knowledge (i.e., terms, formulas, and diagrams). • Determine what will be important to evaluate in the next phase.	• Apply and transfer their knowledge and skills in new contexts. • Relate past experience to current activities. • Communicate their current ideas.
Evaluation	• Assess what students understand and can do at this point. • Encourage students to be metacognitive. • Determine what should occur in subsequent learning cycles.	• Assess their own understandings as they solve problems. • Be metacognitive about their learning.

The learning cycle has been embraced in science teacher education as a suitable instructional model (Rubba, 1992) consistent with the goals of the *National Science Education Standards* (*NSES*) (National Research Council [NRC], 1996). Science teacher educators may be disappointed to find, however, that preservice teachers possess a wide range of understandings about the learning cycle, even after receiving extensive instruction about it (e.g., see Settlage, 2000). In addition to a lack of understanding of the learning cycle, research suggests teachers' perceptions of their roles and beliefs about teaching and learning may contribute to a lack of implementation of the learning cycle in their classrooms (Glasson & Lalik, 1993). Furthermore, this model often differs significantly from the kind of instruction prospective teachers received in their own K-12 science experiences. For example, many of our preservice elementary teachers have experienced "activitymania" (Moscovici & Nelson, 1998), in which their teachers presented a series of disconnected activities that quickly moved from one concept to the next. Thus, we often encounter the belief that teaching more than one activity related to a single concept is redundant. As a result, we find our students often fail to grasp the manner in which conceptual development occurs through *multiple* learning experiences that build upon one another.

As emphasized earlier, preservice teachers enter their science methods courses following K-12 experiences that may reflect more didactic forms of science instruction. Providing opportunities for preservice teachers to experience this approach *as a learner* can be critical to their understanding of the learning cycle. Also necessary, however, is the opportunity to plan instruction using the learning cycle *as a teacher.* As science teacher educators, we believe that the learning cycle model itself can provide a venue for sequencing learning experiences to help preservice teachers understand and apply this approach. The purpose of this report is to describe how we developed and implemented this model in our elementary science methods course. Though we present this approach from our perspective as science teacher educators, we also suggest directions for research regarding the impact of this model on preservice teachers' understanding of the learning cycle. In the following sections, we develop a "conceptual storyline" (Ramsey, 1993) that details course activities for each of the five phases of our instruction about the learning cycle. A conceptual storyline differs from a traditional lesson plan in that it provides a more detailed narrative account of the major concepts and how those are developed throughout the activities of the learning cycle. We hope that this rich account can help other science teacher educators both understand and consider the applicability of this instructional model to their own context.

Engagement Phase

Consistent with the intent of the Engagement phase of the learning cycle, our initial activity is intended to elicit preservice elementary teachers' prior knowledge and beliefs about teaching. Card-sort activities have been utilized by other science teacher educators as a way to elicit teaching orientations (Friedrichsen & Dana, 2003) as well as beliefs about the nature of science (Cobern & Loving, 1998). We developed a modified card-sort activity (see Appendix A) in which preservice teachers select and sequence learning experiences into learning cycles.

We began by using examples of learning cycle lessons from our own teaching experiences as well as those described in the literature (e.g., see Abell & Volkmann, 2006; Moyer, Hackett, & Everett, 2007). In addition to the five activities included in the learning cycle example, we add alternative activities that could be utilized within that learning cycle as well as "distractors" or more didactic and "cookbook" activities that would be considered either antithetical to the learning cycle approach and/or only loosely connected to the conceptual storyline of that learning cycle. For example, we used the hypothetical examples of singing a song about the rock cycle, using a multimedia CD to read about circuits, or watching a video about sound in lieu of hands-on activities. Each set of cards thus included eight to ten activities relating to the concept and ranging from highly teacher-centered to highly student-centered activities. These also varied in the degree to which one might consider them to be doing science (Sullenger, 1999). Working in small groups, our students were first asked to reach a consensus on the selection of five activities they felt best related to the concept(s) or "fit" together. Next, we asked groups to arrange the activities they selected into what they felt would be an appropriate sequence for instruction. Using their card-sort task, Friedrichsen and Dana (2003) found "it was not how the teacher sorted particular cards, but what the teacher said during the sorting that offered the most insight into their science teaching orientation" (p. 295). Keeping this in mind, we asked each group to provide a rationale for their selection of each activity as well as its place in the instructional sequence. Common preconceptions and orientations toward teaching and learning science that we encountered in this phase of instruction included more teacher-centered and didactic instruction that placed the teacher in the role of dispenser of knowledge. Furthermore, in our experience, students tended to draw upon activities similar to those they have experienced as learners and shy away from selecting unfamiliar activities. Their own content knowledge also played a significant role in their decisions about what activities to choose to best develop the concept(s). For example, students often failed to see the value of particular activities in addressing potential misconceptions, and excluded those from their selection as a result. Figure 2 highlights an example that typifies students' performance on this task.

Exploration Phase

Because the learning cycle differs so greatly from the type of science instruction many of our students experienced as learners, we felt it was critical to provide them with firsthand experiences of learning science content through this approach. Over the course of several class sessions, students participated, as learners, in four different learning cycles that focused on content appropriate to the elementary classroom. The lessons are intended for a range of elementary learners and addressed a variety of content areas, including physical, life, and earth/space science. This provided an opportunity for prospective teachers to experience learning through the learning cycle and obtain evidence of the model's effectiveness in impacting their own understanding of the content. For example, our students were often surprised to find that they had misconceptions about the science concepts they would be expected to teach elementary students. By working through their misconceptions, they were able to understand how the lesson might similarly impact their own students.

The particular model lessons used in this phase were not important; rather, they provided a diverse illustration of the many ways in which the learning cycle might be utilized to teach a variety of concepts. It was the debriefing following each lesson (see next phase) that was critical in drawing prospective teachers' attention to the flexibility of the model and how the purpose of each phase of instruction contributes to the conceptual storyline. Other science teacher educators may select learning cycles specific to their own students' needs. For example, our secondary science education colleagues have recently begun using our approach, and, in doing so, they use example lessons that focus on concepts and strategies appropriate to the high school level.

Figure 2. Example of Students' Selection and Sequencing of Learning Experiences from the Card-Sort Task

Sequence of Instruction	Selected Activity	Rationale
First	Students, in pairs, explore a multimedia CD that explains how current travels in a simple circuit. They answer a series of questions at the end of the module to test their understanding.	*This test would let the teacher know what students understand about circuits.*
Second	Students, in groups, play the Operation Game. They then explain individually, in writing, how the game relates to what they know about simple circuits. They identify the path of the current as it travels through various parts of the game as well as why the buzzer sounds and the patient's nose lights at some times but not others.	*This would be a fun way to show students how circuits work.*
Third	Students are provided with a battery, bulb, and wire and are challenged to find ways to make the bulb light. They keep a list of "Ways that Work" as well as "Ways that Don't Work," then look for patterns in their observations to develop "rules" for lighting the bulb. Students compare their rules in pairs and negotiate any disagreement by retesting their configurations of battery, bulb, and wire to observe whether the bulb lights.	*We did this in physics class and think this is a great hands-on activity.*
Fourth	The teacher introduces vocabulary terms to students such as *circuit*, *conductor*, *insulator*, and *current*. Students then create an illustrated dictionary in their lab notebooks, drawing pictures that convey the meaning of each of these terms based on their own observations and investigations.	*After the students have built a circuit, the teacher can bring them back together to begin their dictionary.*
Fifth	Students, working in pairs, design their own circuit quiz-boards by following instructions provided by the teacher and filling in questions and answers of their own choosing. Some students provide words and definitions, while others list math problems and answers. Pairs trade quiz-boards with other groups and try to answer the questions correctly.	*Students get a chance to build circuits themselves and challenge one another with their quizzes.*

Activities *Not* Selected for Inclusion	Rationale
Students are provided with a flashlight, which they take apart to identify the circuitry found within. They create diagrams and written explanations of how a flashlight works, identifying the path of conductors through which the electric current travels as well as the insulators through which current cannot travel.	*We liked this activity, but it didn't fit with the other activities we selected.*
Students, in groups, design experiments to determine the effect that various factors (e.g., number of bulbs, number of batteries, and length of wires) have on the brightness of the bulbs in a circuit. Students use the brightness of the bulbs as an indicator of the amount of current flowing through the circuit.	*We thought the type of circuit makes a difference in the current, not the brightness of the bulbs.*
Students are given a "mystery box" in which there may or may not be an electrical connection. (There may be batteries, bulbs, and wires in any configuration inside.) Two wires extend from the side of the box. Students are invited to test their ideas and explain what they think is inside the box using evidence from their investigations.	*This activity would be challenging for students.*

Following participation in each learning cycle, preservice teachers were given access to the written lesson plans as a model for preparing their own lesson plans (see Elaboration phase of instruction). Though providing such models may evoke concerns that preservice teachers will simply copy or imitate the example, McTighe and O'Connor (2005) indicate that providing multiple models can help avoid this problem. When students see several exemplars illustrating different ways in which the learning cycle can be implemented, they are less likely to view this as a cookie cutter approach. Specifically, we highlighted the flexibility of the learning cycle and the ways in which similar activities can be used in different phases of the lesson for different purposes. For example, two of the example lessons include children's literature. In one case, a trade book is used to engage learners in considering their own ideas about the concepts, whereas in another, a trade book is used as an assessment activity in which students critically evaluate the scientific accuracy of the content.

Explanation Phase

The Explanation phase is critical for sense-making following the initial activities of the lesson. Course activities in this stage of our instruction focused on clarifying the purpose of each phase of the learning cycle based on the model examples in which preservice teachers participated. Following each lesson, preservice teachers worked in groups to debrief their experience by completing a two-column chart outlining the specific activities of the teacher and students in each phase of instruction (see Figure 1). This activity is intended to shift preservice teachers' perspectives from that of being a learner to that of being a teacher. Through this process, we emphasized the role of the teacher in facilitating the learning experience and highlighted strategies such as productive questioning (Martens, 1999). Additionally, we focus on understanding the model further through professional readings about this approach that were written from the perspectives of science educators and classroom teachers (e.g., Brown, 2006; Lorsbach, n.d.; Moscovici & Nelson, 1998). It is important to note that this is the first time that preservice teachers are formally introduced to the vocabulary to describe each phase of the learning cycle (e.g., Engagement and Exploration). This aspect of our instruction is discussed explicitly to illustrate the premise of exploration before introducing the concept on which the learning cycle is based.

Elaboration Phase

To apply their new understandings, preservice teachers next planned their own learning cycle and developed a conceptual storyline based on a concept or big idea selected from the *NSES* (NRC, 1996). Harking back to the initial card-sort task, they began developing a collection of activities that related to the focal concept. Just as in the initial card-sort activity, they selected and sequenced five activities that best formed a coherent conceptual storyline. Preservice teachers then prepared an outline of their lesson idea that included their rationales for how each activity related to the concept of focus and targeted potential student misconceptions. Outlines were brought to class, and students worked in small groups to provide feedback to one another on the selection and sequencing of their activities in terms of the learning cycle model. Following this round of peer review, outlines were further refined and handed in to the instructor for additional feedback.

Next, preservice teachers articulated, in writing, the conceptual storyline for their lesson. Unlike a traditional lesson plan, this storyline needed to provide a rich narrative describing each phase of instruction, including specific details about their rationale for the overall lesson and specific choice of activities, what they and students will say and do, questions that will be utilized to facilitate discussion, how materials will be managed, what criteria they will use to evaluate student work, and so on. Finished lesson plans were usually six to ten single-spaced pages in length. The purpose of this level of detail was to enable the instructor to make a valid assessment of preservice teachers' depth of understanding of the learning cycle and instructional decisionmaking in the design of the lesson; however, preservice teachers consistently reported that this was a valuable exercise that helped them realize just how much they must consider in designing effective instruction. We emphasized to our students that even in briefer versions of lesson plans like these that they would write in the future, they would still need to think through their lessons in this same depth.

Overall, our assessments of students' completed plans since implementing this approach to teaching about the learning cycle indicate that a greater number of students exhibit an in-depth understanding of the learning cycle model. For example, in previous semesters, we typically had about a 60 to 80% success rate in terms of students whose final lesson plans fit the model in regards to the appropriate selection and sequencing of activities to develop the concept. With this new approach in which we use the learning cycle as a model to teach preservice teachers about the learning cycle model, we have achieved a 100% success rate; that is, *all* of the students in our courses were able to select and sequence learning experiences consistent with the learning cycle model. While these results may be atypical, they are nonetheless encouraging, and future research should be conducted to provide an empirical basis for claims about the effectiveness of our approach. For example, we suspect that the process of developing an initial outline, having the opportunity to discuss their plans in class, and receiving peer review and instructor feedback prior to completion of their conceptual storylines is an important scaffold—in addition to their multiple experiences with the learning cycle—as learners.

Evaluation Phase

While preservice teachers' own learning cycle lessons could serve as a summative assessment for the faculty member to evaluate, it was also important for preservice teachers to self-assess and reflect on their new understandings about this model as well as teaching and learning science. To accomplish this, we asked our students to revisit and critique their initial selection and sequencing of the activities from the card-sort in the Engagement portion of our instruction. In our experience, preservice teachers often changed not only the activities they originally selected from among the cards but also the sequence in which they would use the activities. They also recognized that the same activity might be used in different phases of the 5E Model, depending on the purpose and way in which it was introduced to students. Furthermore, preservice teachers were able to suggest modifications to the activities they initially selected that would make them more appropriate to the learning cycle model. Overall, they were more adept at identifying learning experiences that would be central to developing the conceptual storyline. Figure 3 highlights an example that typifies the shift in students' knowledge of the learning cycle.

Figure 3. Example of Students' Revised Selection and Sequencing of Learning Experiences Following Instruction

Phase of Lesson	Selected Activity	Rationale
Engagement	Students are provided with a battery, bulb, and wire and are challenged to find ways to make the bulb light. They keep a list of "Ways that Work" as well as "Ways that Don't Work," then look for patterns in their observations to develop "rules" for lighting the bulb. Students compare their rules in pairs and negotiate any disagreement by retesting their configurations of battery, bulb, and wire to observe whether the bulb lights.	*We still like this one and think it would be a fun way to start the lesson and help students learn about a complete circuit. Asking them to predict whether it would work could be a way to assess their prior knowledge.*
Exploration	Students, in groups, design experiments to determine the effect that various factors (e.g., number of bulbs, number of batteries, and length of wires) have on the brightness of the bulbs in a circuit. Students use the brightness of the bulbs as an indicator of the amount of current flowing through the circuit.	*This one has the students go beyond the first activity by exploring different materials. We probably wouldn't have them discuss current until the next part, though.*
Explanation	The teacher introduces vocabulary terms to students such as *circuit*, *conductor*, *insulator*, and *current*. Students then create an illustrated dictionary in their lab notebooks, drawing pictures that convey the meaning of each of these terms based on their own observations and investigations.	*We still think the teacher needs to bring the students back together at this point. This would be a good way for students to put these ideas in their own words.*
Elaboration	Students, in groups, play the Operation Game. They then explain individually, in writing, how the game relates to what they know about simple circuits. They identify the path of the current as it travels through various parts of the game as well as why the buzzer sounds and the patient's nose lights at some times but not others.	*We moved this activity here because now that students know about circuits, conductors, insulators, etc., they will be able to make sense of the game.*
Evaluation	Students are given a "mystery box" in which there may or may not be an electrical connection. (There may be batteries, bulbs, and wires in any configuration inside.) Two wires extend from the side of the box. Students are invited to test their ideas and explain what they think is inside the box using evidence from their investigations.	*After talking about this activity with [our professor], we have a better idea of what it involves. This would be a good way to have students rely on their prior knowledge to solve the mystery—and it would be fun. If it's too challenging, it might be because we need to reteach something.*

Activities *Not* Selected for Inclusion	Rationale
Students, in pairs, explore a multimedia CD that explains how current travels in a simple circuit. They answer a series of questions at the end of the module to test their understanding.	*We realize that this is not testing students' prior knowledge now, just the knowledge they are getting from the CD.*
Students are provided with a flashlight, which they take apart to identify the circuitry found within. They create diagrams and written explanations of how a flashlight works, identifying the path of conductors through which the electric current travels as well as the insulators through which current cannot travel.	*We still like this activity and could probably use it instead of the Operation Game to help extend students' ideas about circuits.*
Students, working in pairs, design their own circuit quiz-boards by following instructions provided by the teacher and filling in questions and answers of their own choosing. Some students provide words and definitions, while others list math problems and answers. Pairs trade quiz-boards with other groups and try to answer the questions correctly.	*They would just be copying the teacher's directions here rather than exploring how to build a circuit game on their own.*

Though students completed this evaluation with their original group members and shared their ideas through whole-class discussion, we also encouraged students to reflect individually on their new understandings. As one of our students wrote,

> *I really like the techniques we have learned in our class about the learning cycle. This technique has created a whole new perspective for me of what it means to teach science. In class during the sequencing activity, our group was given a set dealing with electrical circuits. We disagreed over whether one part would be a good idea to teach in our classroom. "The teacher introduces vocabulary terms to students such as* circuit, conductor, insulator, *and* current. *Students create an illustrated dictionary in their lab notebooks, drawing pictures that convey the meaning of each of these terms based on their own observations and investigations. I thought this would be a good idea to use in the classroom. I think there is a time where a teacher needs to build knowledge by teaching students the proper terms of what they are seeing. This knowledge will help add meaning to other things they are seeing. I think that adding pictures at the bottom will help students apply the definitions to what they have witnessed in class.*

As illustrated above, these reflections allow us another means to assess the change in preservice teachers' ideas about teaching and learning science and the depth to which they understand the purposes of the different phases of the learning cycle approach.

Conclusion

In the preceding sections, we have outlined a conceptual storyline that illustrates the way in which we help prospective teachers understand the learning cycle model. Through applying the learning cycle model in our own instruction, we have found an effective means for teaching our preservice teachers about this approach. In essence, we are "practicing what we preach" by modeling the same kind of instruction we expect from them. The activities we developed for our own learning cycle function together as a conceptual storyline that helps our students develop a deeper understanding of powerful ways to select and sequence learning activities for their own instruction. We find it especially helpful in addressing students' preconceptions about the "redundancy" of providing multiple learning experiences about the same concept.

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Appendix A: Card-Sort Sets of Activities for Learning Cycles

Set #1: The goal of this lesson sequence is to help students understand science as a process of inquiry and to make connections between the work of scientists and their own classroom science activities. This sequence is part of a broader goal for helping students understand the nature of science.

- Students are asked to draw a picture of a scientist and explain what they think scientists do.
- Students design and conduct their own experiments to investigate plant growth. Their findings are shared in a mini-conference at family science night.
- Students, in pairs, read nonfiction books about the work of scientists and then share their ideas about what they read in a whole-class discussion.
- Students make a Venn diagram comparing their own work in science class to the work that scientists do.
- The teacher invites a local biologist to visit the class as a guest speaker. Students ask this scientist questions about the work he or she does with corn plants.
- The class takes a field trip to a local farm to hear about ways farmers are trying to increase their crop yield.
- The class adopts a plot of land in their schoolyard and creates a garden to help beautify the school.
- Students read Chapter 5 of their science book, which discusses how plants grow. They compare their ideas in small groups and discuss how the ideas they read relate to what they have been learning.
- Students bring in different food dishes from home in which corn is a main ingredient. They discuss the importance of corn to different cultures.

Set #2: The goal of this lesson sequence is to help students understand how shadows are formed and the factors that influence the size and shape of shadows. This sequence will prepare students for future lessons focusing on the behavior and properties of light.

- The teacher reads *Bear Shadow*, a story by Frank Asch (1988) about a bear that attempts to escape a shadow that seems to be chasing him. Students are asked to think critically about what aspects of the story could be real or not in terms of Bear's shadow.
- As a class, students go on a "shadow hunt"—identifying different objects that make shadows, where shadows appear, and what light sources are present and their location. They draw pictures to record what they observe.
- In pairs, students make shadows of their own using flashlights and a variety of objects provided by the teacher. Students record their ideas about what causes a shadow as well as what causes a shadow to be different sizes or shapes.
- The teacher poses the following problem to students and asks them to respond individually: The local puppet show will soon be putting on a shadow play production of *The Three Bears*. Unfortunately, the three bear-shaped puppets they have are all the same size! How will they ever be able to make Momma, Poppa, and Baby Bear using the same sized puppets? Using what you know about shadows, explain how you think they might solve this problem.
- The teacher explains to students that the size of a shadow is dependent on the distance of the object from the light source as well as the distance of the object from the surface on which its shadow falls. The teacher guides students in constructing diagrams to depict these two factors.

- Students draw pictures to illustrate ways to make shadows bigger and smaller. They share their pictures in small groups and compare their ideas in a whole-class discussion.
- Students work in groups to design investigations to answer the question, "What effect does the distance of the light source from the object have on the size of the shadow that is produced?"
- Using a stuffed teddy bear, the teacher demonstrates different ways to change the size of a shadow by projecting light from the overhead projector. She moves the teddy bear closer and farther from the screen, and then moves the overhead projector closer and farther from the teddy bear. She then brings out a bigger stuffed bear and asks the class to predict what she could do to make the shadows of the two bears the same size.

Set #3: This lesson sequence is designed to help students understand how rocks are formed and to appreciate the diversity of rocks that exist. It is part of a larger unit on the rock cycle.

- Students use *Golden Guides*™ (kid-friendly field guides) with information about different kinds of rocks to identify samples of rocks provided by the teacher (or brought from home).
- Students are asked to bring in a rock from home. They share these in a circle, and the teacher closes the sharing session by asking students to write about what they think a rock is and where rocks come from.
- Students are provided with a sample of rocks, which they sort based on characteristics they determine such as color, texture, and whether they float/sink. The teacher challenges students to think of criteria that would/would not be useful to classify rocks (e.g., two rocks may be the same type of rock but be a different size and shape).
- Students make posters of the rock cycle, using their textbook diagram as a guide, and hang these posters in the classroom.
- Students, as a class, brainstorm a list of ways that people use rocks. Students generate examples ranging from pet rocks and landscaping to building materials and the basis for sculptures in art.
- The class participates in a "rock exchange" with a classroom in another state, preparing a box with rocks found in their local area to send to them. Once they receive the box from their "rock pals," they compare the properties of rocks they receive to rocks found in their local area and suggest reasons they might be the same and/or different.
- The class takes a field trip to the nearby state park, where a park ranger gives a talk about the local geology of the area and how it has changed throughout history.
- Students explore an interactive website that explains the various stages of the rock cycle and how rocks are formed and reformed through this cycle.

Set #4: The goal of this learning cycle is to help students understand that each plant or animal has different structures that serve different functions in growth, survival, and reproduction.

- Students make a collage using cut-out images from magazines and newspapers that illustrate the diversity of a particular structure among a group of animals and then writes a paragraph about their ideas. For example, one student creates a collage showing the many different kinds of feet that birds have, and then he or she writes a paragraph that explains how having different types of feet might help birds do things to help them to survive.

- Students use different tools to represent the variety of beaks of different birds (e.g., pliers, a straw, or tongs) and explore how much and what kind of "food" these birds might be able to eat in different habitats. The teacher has prepared the "habitats" in advance, and each contains a different variety of foods. Students conclude that their "birds" might not survive well in some habitats because they would be unable to eat enough food.
- The teacher presents each group of students with a variety of bird feathers (from a single type of bird) and magnifying lenses. Students explore dropping and waving the feathers around and develop detailed drawings in their science notebooks that illustrate the differences and similarities they observe between the different feather types. Students draw inferences about how having different types of feathers help a bird survive (e.g., down feathers are soft and help keep the bird warm, while flight feathers are rigid and help the bird push the air).
- Students look through *Golden Guides*™ to learn about different species of birds found in their area. Parents are encouraged to help their child birdwatch in their backyard and identify different species they see.
- Students compare birds found in their local area to birds found in different places around the world. Students use geographical resources to learn more about the environments in which the birds live and then compare different adaptations the birds have to help them survive in those environments. Each group focuses on a specific pair of birds (one local and one from afar) to compare and share with the class.
- The teacher asks students to imagine what their life would be like if they had a beak instead of a mouth. During circle time, students go around and share something they think would be different, living with a beak.
- A guest speaker from the raptor rehabilitation program brings in several birds and discusses the different adaptations raptors have that help them survive by catching and eating their prey.
- Students read a chapter in their science book about animal and plant diversity. Afterwards, they discuss factors that affect the survival of different species.
- The class places two bird feeders outside of the classroom with very different kinds of foods. They keep track of the different species of birds that visit one feeder versus the other.

Set #5: The goal of this lesson sequence is to help students develop an understanding of a simple circuit and a model for the way electric current travels through a circuit. It is the first lesson in a unit that explores electrical circuits.

- Students, in groups, play the Operation Game. They then explain individually, in writing, how the game relates to what they know about simple circuits. They identify the path of the current as it travels through various parts of the game as well as why the buzzer sounds and the patient's nose lights at some times but not others.
- Students, working in pairs, design their own circuit quiz-boards by following instructions provided by the teacher and filling in questions and answers of their own choosing. Some students provide words and definitions, while others list math problems and answers. Pairs trade quiz-boards with other groups and try to answer the questions correctly.

- Students are provided with a battery, bulb, and wire, and are challenged to find ways to make the bulb light. They keep a list of "Ways that Work" as well as "Ways that Don't Work," then look for patterns in their observations to develop "rules" for lighting the bulb. Students compare their rules in pairs, and negotiate any disagreement by retesting their configurations of battery, bulb, and wire to observe whether the bulb lights.
- Students are provided with a flashlight, which they take apart to identify the circuitry found within. They create diagrams and written explanations of how a flashlight works, identifying the path of conductors through which the electric current travels as well as the insulators through which current cannot travel.
- Students, in groups, design experiments to determine the effect that various factors (e.g., number of bulbs, number of batteries, and length of wires) have on the brightness of the bulbs in a circuit. Students use the brightness of the bulbs as an indicator of the amount of current flowing through the circuit.
- The teacher introduces vocabulary terms to students such as *circuit*, *conductor*, *insulator*, and *current*. Students then create an illustrated dictionary in their lab notebooks, drawing pictures that convey the meaning of each of these terms based on their own observations and investigations.
- Students, in pairs, explore a multimedia CD that explains how current travels in a simple circuit. They answer a series of questions at the end of the module to test their understanding.
- Students are given a "mystery box" in which there may or may not be an electrical connection. (There may be batteries, bulbs, and wires in any configuration inside.) Two wires extend from the side of the box. Students are invited to test their ideas and explain what they think is inside the box using evidence from their investigations.

Set #6: In this lesson sequence, students consider the question, "What causes sound?" The goal of this lesson sequence is to help students understand that "Sound is produced by vibrating objects." The mechanism of sound production is an important precursor to understanding other properties of sound, such as "pitch," so it is the first lesson in a curriculum unit about sound.

- Students partner together to design and build an instrument. The whole class listens as each pair shares their instrument and presents how it produces sound.
- The students make sounds by using different materials that the teacher has placed at several stations around the classroom. They pluck rubberbands, blow into bottles of various shapes, and try out various percussion instruments while recording ideas and observations in their science notebooks.
- The teacher reads aloud the children's book *The Very Quiet Cricket* by Eric Carle (1997). Here is a brief synopsis of what the book is about: A cricket is born who cannot talk! A bigger cricket welcomes him to the world, then a locust, a cicada, and many other insects, but each time the tiny cricket rubs his wings together in vain; no sound emerges. In the end, however, he meets another quiet cricket, and manages to find his "voice": "And this time . . . he chirped the most beautiful sound that she had ever heard."
- Students make and use "string telephones" out of tin-cans and string. Their recorded observations and ideas about what they think is happening to the sound become the focus of a class discussion.

- Students are given the challenge to "Make the Sound Stop!" Each group has a buzzer and a limited amount of materials and time to figure out a way to stop the sound—without turning off the buzzer, of course!
- Students are given a bag of materials: a tuning fork, small rubber hammer to strike the tuning fork, a jar of water, and a ping-pong ball. The teacher encourages students to find different ways to use the materials to make sound.
- Students write down three things that they know about sound on post-it notes. Groups of students compare and contrast their ideas with each other, noting that they don't all agree. This leads to a whole class discussion about students' ideas.

Set #7: The goal of this lesson sequence is to help students understand that almost all kinds of animals' food can be traced back to plants. This lesson is within a unit focused on the interdependence of organisms—to each other and to their environment.

- The teacher shows a metal chain with links to students. She uses this as a model to represent what a food chain is. Students then use strips of paper to write organism names and link them to create their own "food chain." The teacher staples all of the food chains onto a bulletin board with a large sun in the center.
- Students choose a group of animals that interest them such as pets, sea creatures, insects and spiders, etc. The teacher (with support from her school librarian) helps students find books and Internet resources so they can find out what their chosen animals eat. When students present their findings, the class constructs a Venn diagram: two overlapping circles labeled "Animals that Eat Animals" and "Animals that Eat Plants" to consider food resources.
- Students are given signs that have different plant and animal names and pictures on them. Students consider different relationships of who eats what, physically representing relationships by joining hands. At the conclusion, the teacher asks students to fill out an *Exit Ticket:* Your friend's younger brother says, "Almost all kinds of animals can be traced back to plants." Do you agree or disagree? Why do you think so? Explain and then draw an example to support your answer.
- The teacher asks students to sort common food items (pictures, toys, or real) into three categories: (1) comes from a plant, (2) comes from an animal, or (3) both. Students work in small groups to discuss and sort the foods. Students write names of food items on a large chart drawn on the class chalkboard. The whole class then discusses whether plants and/or animals are needed as food.
- Students write responses to the following questions:
  - What would happen to an owl living in a forest if all of the mice could not find food? Why?
  - What would happen to the bees in an area if all the flowering plants died? Why?
- The teacher reviews the definitions of a *carnivore*, *omnivore*, and *herbivore*. Students look in old magazines to find pictures of each type of animal to place on a poster board.
- Students want to know what foods like marshmallows, candy, and mayonnaise are made of because the source isn't obvious to them. Students bring in food labels and work in groups to figure out if the ingredients can be traced to plants or not.

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