Reading to Learn Science as an Active Process

Using learning cycles in the classroom can actively engage students in thinking, talking, reading, and writing about science

Victoria Ridgeway Gillis and Gregory MacDougall

Science teachers often think of reading as a passive activity and science as a hands-on active process. As middle and high school science teachers, we came to view reading as we viewed science—a cognitive process in which learners actively construct their knowledge in a transaction with the text. As we implemented active reading strategies in our hands-on classrooms, two things became apparent to us: first, our teaching was more efficient as students took responsibility for acquiring information outside of class; and second, we often noticed dramatic increases in student achievement, particularly with struggling learners.

But how did we do this? How can science teachers help students learn to read science and at the same time teach the content? Can these tasks be accomplished simultaneously? Thankfully, yes. One way to do so is by incorporating classroom strategies that actively engage students in thinking, talking, reading, and writing about science. Strategies must be chosen carefully depending on the target content, the learning context, and the student audience. How do teachers maximize the probability that strategies will be effective? One answer is to use a learning cycle as a guide when designing lessons. In this article, we describe learning cycles in science and reading, including processes involved, and teaching strategies that maximize student involvement and learning.

Learning cycles

Learning cycles independently evolved in the separate fields of science and reading. The origin of learning cycles in science education is generally attributed to Karplus (1964). Others have modified this cycle. Figure 1 summarizes, though not comprehensively, several science learning cycles.

In this section, we refer to the learning cycle phases as (1) *exploration*, (2) *concept invention*, and (3) *application*. The purpose of the *exploration* phase is to get students ready to learn new concepts through activities designed to raise student interest and identify levels of prior knowledge. In science, it is particularly important to attend to prior knowledge because many students hold scientific misconceptions (Guzzetti et al. 1993). The exploration phase is critical in order to identify misconceptions that will be addressed in the concept invention phase. Although some teachers tend to skip the exploration phase, it is especially important for students in the concrete operational developmental stage (Abraham and Renner 1986).

FIGURE 1

Summary of Learning Cycles in Science Education.

Karplus (1964)	Renner (1985)	Abraham and Renner (1986)	Lawson (1988)	Bybee (1989) 5E	Eisencraft (2003) 7E
Exploration	Exploration	Gathering Data	Exploration	Engagement Exploration	Elicitation Engagement Exploration
Invention	Conceptual Invention	Conceptual Invention	Term Introduction	Explanation	Explanation
Discovery	Expansion of Idea	Conceptual Expansion	Concept Application	Elaboration Evaluation	Elaboration Evaluation Extension

FIGURE 2

Summary of Learning Cycles in Reading Education.

Betts (1946)	Herber (1970)	Barton and Jordan (2001)	Richardson and Morgan (2002)	Vacca and Vacca (2005)
Readiness	Preparation	Preactive	Prepare	Pre-reading
Directed silent reading	Guidance	Interactive	Assist	Reader-Text Interaction
Comprehension check and discussion Oral rereading Follow-up activities	Independence	Reflective	Reflect	Post-reading

The *concept invention* phase builds on the exploration phase and involves information input, usually from the teacher or a text. In concept invention, the teacher scaffolds students' learning using a variety of instructional strategies. This phase is traditionally viewed as the actual "teaching and learning" phase, in which students begin to understand concepts as the teacher facilitates student interaction with resources using multiple learning styles.

In the *application* phase, the teacher uses strategies that require students to apply the newly constructed concepts to novel problems and situations. Students take ownership of the new knowledge as they organize, use, and understand the knowledge from a variety of personal and social perspectives. As students apply their new knowledge, additional information may be required and the cycle repeats. In this way, the application phase may evolve into the exploration phase of another learning cycle.

Similar three-phase learning cycles have been described in the reading field. In a typical learning cycle in the reading field, the teacher (1) prepares students for reading by activating prior knowledge, focusing attention on important ideas and generating a purpose for reading; (2) guides or scaffolds students' reading; and (3) helps students transform and personalize information through reflection (Alvermann, Phelps, and Ridgeway 2007). Figure 2 summarizes learning cycles described in reading education.

These processes are similar to those described in science. *Exploration* (science) or *preparation* (reading) involves preparing students to learn science, whether through hands-on activities or through reading. *Concept invention* (science) or *guiding and scaffolding* (reading) involves guided learning, whether through discussion of the results of a scientific exploration or reading. *Application* (science) or *reflection* (reading) involves organizing the new knowledge gained from the results of the exploration or from reading to construct in-depth understanding that goes beyond the classroom.

Figure 3 provides a visual summary of a learning cycle that combines elements of the reading and science learning cycles, as we have described them. For clarity, and because the terms describe cognitive processes involved in each phase, we will adopt the learning cycle terminology used by Barton and Jordan (2001) for the remainder of this article: *preactive*, *interactive*, and *reflective*. These terms loosely correlate with the three categories of *exploration*, *concept invention*, and *application/reflection* already described.

Learning cycle strategy selection

Strategies selected for a lesson depend on a variety of factors. When choosing a strategy for the *preactive* phase, teachers should consider whether students have sufficient prior knowledge about the topic. Strategies that involve brainstorming work very well in the preactive phase when student prior knowledge is sufficient, for example: brainstorming and mapping responses or generating questions.

When prior knowledge is insufficient, several appropriate strategies can prepare students to read, such as

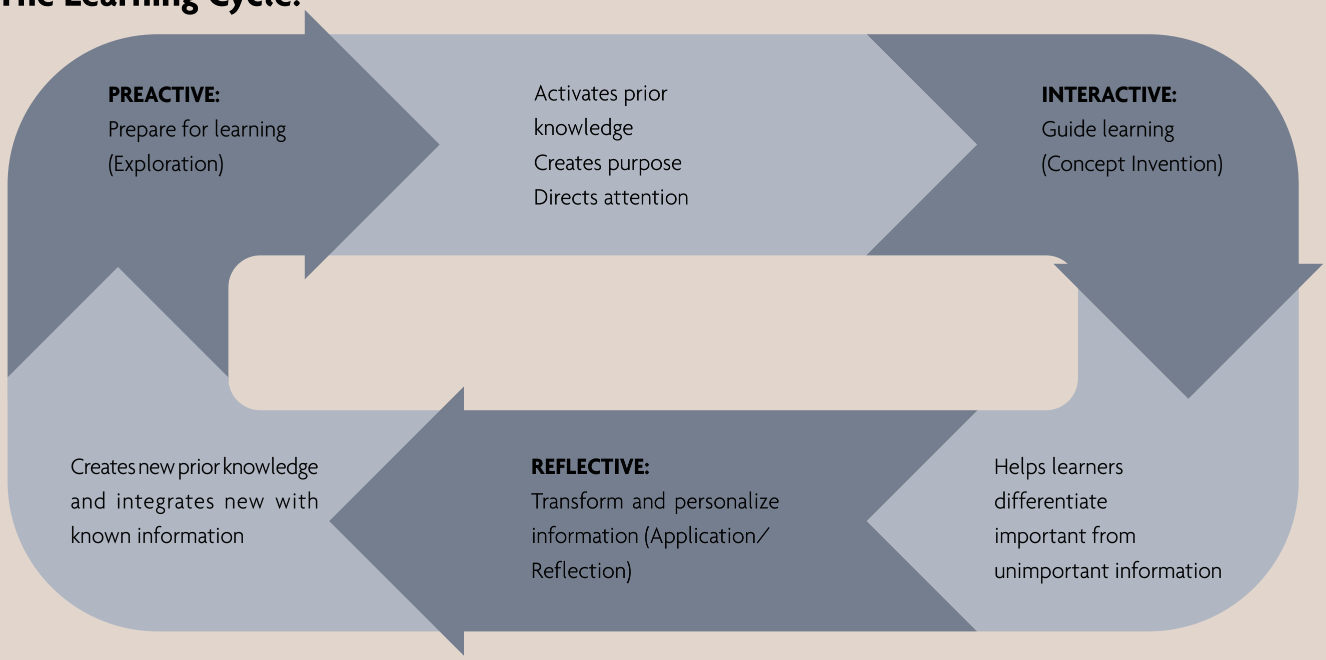
- an anticipation guide (Readence, Bean, and Baldwin 1998),
- a teacher-created graphic organizer that can be used to introduce vocabulary,
- previewing the text to be read (e.g., heading, subheadings, pictures, graphics), and
- conducting hands-on explorations.

An anticipation guide consists of true/false statements that students respond to and discuss before they read (Figure 4, p. 48). Students may reflect on their responses to the guide after reading. These guides are composed of statements that focus students' attention on core concepts they will read about in the text and may be designed to address common student misconceptions. [**Note**: See Duffelmeyer 1994 for information on constructing effective anticipation guide statements.] Responses to anticipation guide statements generally lead to healthy class discussion, which increases student motivation and prepares students to actively read text.

The purpose of the *interactive* phase is to foster student-text interactions that result in comprehension. When reading, individuals focus their attention on text meaning, monitor their comprehension, adjust their reading rate, and use fix-up strategies when text is confusing. Teachers should use explicit strategies that help novice readers interact with text to ensure understanding. When planning for the interactive phase, teachers should consider the amount of scaffolding students need. Strategies chosen for the preactive phase can serve to guide learning

FIGURE 3

The Learning Cycle.



in the interactive phase. Students might annotate concept maps or graphic organizers, answer questions generated during brainstorming, or reconsider responses to anticipation guides as they read.

High school teachers might use a variety of strategies to promote active reading, such as paired reading or having students or the teacher read text aloud. In paired reading, students read and respond to each other. One student assumes the reader role while a partner assumes the role of summarizer. Students alternate roles as they read. When students read aloud, they should always read familiar text—text they have previously read silently. In addition, students should read aloud to provide support for an answer or refute another student's assertion. One of the most powerful teaching strategies is modeling the comprehension process by thinking aloud while reading text, which makes thinking public. For instance, while reading aloud, the teacher stops to wonder aloud about a point in the text or a vocabulary term, or make a prediction, connection, or an inference.

When students read aloud, they should always read familiar text...

Teachers should assign appropriate chunks of material to be read based on students' abilities, check for student understanding between read-

FIGURE 4

Anticipation Guide Example—Newton's Laws of Motion.

[**Note:** All items except #4 are intended to be true, and #4 is true if air resistance is considered, but false if air resistance is neglected. The ambiguity in question #4 is intended to produce rich discussion and inquiry as students process the text and explore Newton's laws.]

Name____

Date____

Before reading: Place a check mark (✓) to the left of each statement if you think the statement is true.
During or after reading: Revise your responses as you read. Use the space under each statement to note the page and paragraph(s) where you are finding information to support your thinking.

___1. As I sit pushing down on the chair, the chair is pushing up on me.

___2. The head of a hammer can be tightened onto its wooden handle by banging the bottom of the handle against a hard surface.

___3. A seatbelt acts by providing a force to keep you from continuing your forward motion when a car stops suddenly.

___4. If you drop a bowling ball and a baseball off the school roof at the same time, the heavy ball will hit the ground first.

___5. A car moves because as the wheels push on the road, the road pushes back.

FIGURE 5

Graphic Organizer (Concept Map)—Matter.

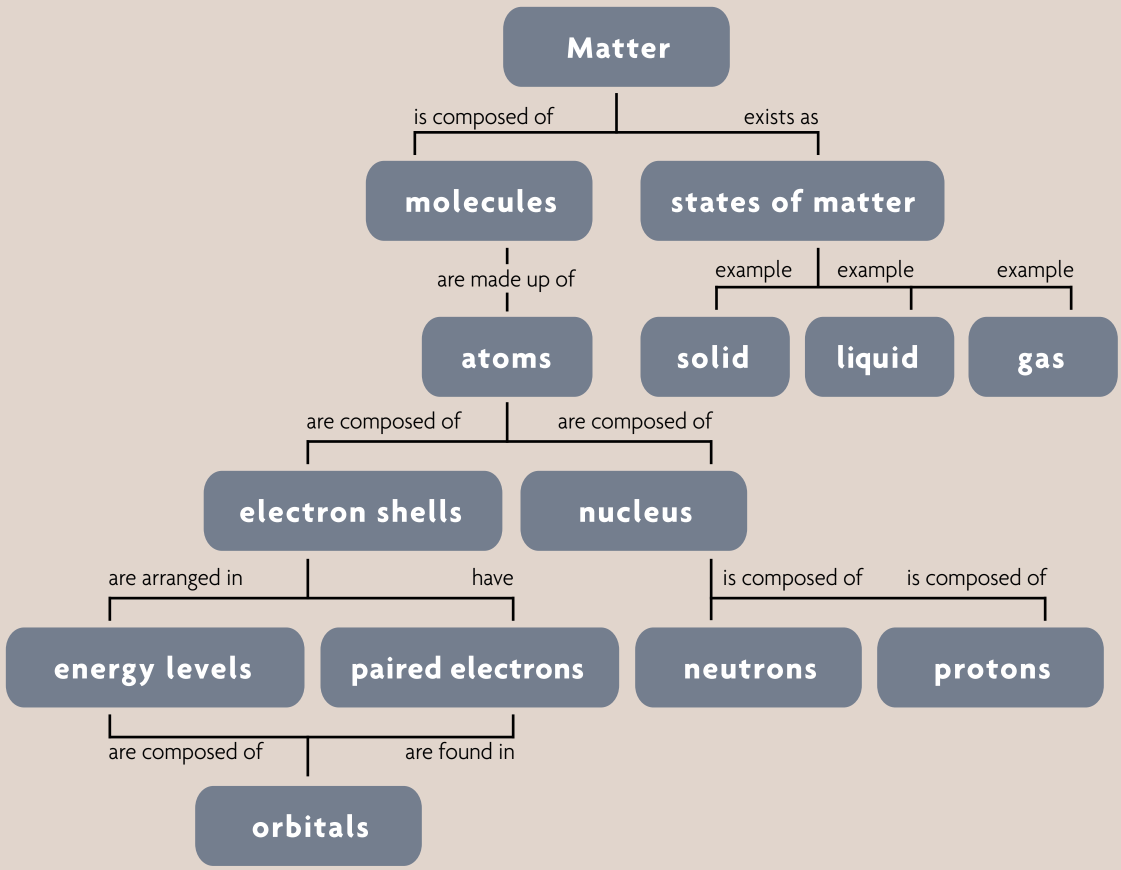


FIGURE 6

Example of Frayer Model—Longitudinal Wave.

Definition	Characteristics
A type of wave in which matter vibrates in the same direction as the wave travels.	Matter moves back and forth a certain distance and at a certain frequency.
Longitudinal Wave	
Examples	**Non-examples**
- Sound - Primary seismic wave - Squeezing and releasing a Slinky	- Ocean waves - Secondary and long seismic waves

ing chunks of text, and model fix-up strategies. Fix-up strategies that work for us include rereading a sentence or a paragraph, reading diagrams or marginal notes, and reading to the end of a sentence or paragraph to see if the confusion is cleared up. Readings may be assigned based on time limits (e.g., read for five minutes) or text-length limits (e.g., read the next two pages). Chunking the reading allows students to think about what they just read.

Several strategies help students interact with text and hold their thinking (Tovani 2000). The INSERT strategy (Vaughn and Estes 1986) involves students using symbols to indicate whether information read is known (✓), new (+), information they disagree with (-), or is confusing (?). This strategy works best when students use sticky notes and summarize text information in their own words along with indicating their response to the information. After students have read, noted their responses, and annotated text, information can be reorganized into a concept map during the *reflective* phase of the lesson. If students have been taught how to make two-column notes (Palmatier 1973) or use text structure to create a chapter map, they might be directed to note the most important information in the text as they read. Regardless of the vehicle chosen to guide student reading, students should be given the opportunity to compare and discuss their text responses in the reflective phase.

FIGURE 7

Semantic Feature Analysis Example—Comparing Inner Planets to Earth.

	Mercury	Venus	Mars
Diameter	-	-	-
Mass	-	-	-
Distance to Sun	-	-	+
Rotation	+	-	+
Revolution	-	-	+

The reflective phase provides students with a way to discuss, think, and write about the scientific concepts and phenomena under study to construct their knowledge. Strategies used in this phase help students transform and personalize the information. Having students create diagrams, concept maps, and other graphic organizers (Figure 5, p. 49); a modified Frayer Model (Barton and Jordan 2001) (Figure 6, p. 49); or a semantic feature analysis (Figure 7) are strategies that promote relational knowledge, emphasizing connections among ideas resulting in an in-depth understanding of scientific phenomena and principles.

Lifelong learners of science

There will always be high school students who remain novice readers, and we must look for ways to help all students succeed. The strategies mentioned in this article have been shown to increase student understanding (Alvermann, Phelps, and Ridgeway 2007; Richardson and Morgan 2002; Vacca and Vacca 2002); however, they are not effective in and of themselves. It is the cognitive activity induced by the strategy that matters (Alvermann, Phelps, and Ridgeway 2007). The learning cycle is an effective instructional framework that is in alignment with the National Science Education Standards (NRC 2000, pp. 34–35). Both in science classes and in daily lives as informed citizens, students need to be able to read and analyze text containing science content. The learning cycle can enable teachers to help students acquire the literacy skills to become lifelong learners of science. ■

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