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ASTE Invited Article

Why the Learning Cycle?

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Abstract

The learning cycle is a way to structure inquiry in school science and occurs in several sequential phases. A learning cycle moves children through a scientific investigation by having them first explore materials, then construct a concept, and finally apply or extend the concept to other situations. Why the learning cycle? Because it is a theory-based design for inquiry that works when implemented well.

Introduction

What happens to the white when snow melts? A 4th grader asked me this wonderful question not long after I had started teaching preservice teachers in college. Of course, giving this child a complete, scientifically accurate answer was inappropriate and beyond this 9-year-old's understanding; but asking the question was not beyond her imagination. How would you respond to this child's question? How about, "Let's experiment to see if we can discover what happens to the white when snow melts." Fortunately, it was winter and one of those rare snow events for our part of the country, so we gathered some snow, took it inside, and watched it melt. To this child, the results of the experiment were clear and the conclusion simply obvious: when snow melts the white disappears! This 4th grader had learned a concept—the white in snow disappears when snow melts—and she learned this after directly experiencing the phenomenon. Of course, your interpretation of the results of the same experiment may include concepts related to states of matter and properties of light and, ultimately, a more sophisticated concept for the question, "What happens to the white when snow melts?"

What can teachers and teacher educators conclude from this account? We must carefully consider *how* children learn and *what* they *can* learn. (My preservice teachers learn this very early in their teacher preparation program.) Let's expand the "how" of children learning by applying the developmental theory presented in Tony Lawson's article, which will be published in the next issue of the *Journal of Elementary Science Education* (*JESE*). You probably recognize the structure of the snow-melting investigation as the learning cycle, but what do you understand about the learning cycle, and, perhaps more importantly, why the learning cycle? We will address "why" later.

The learning cycle is a way to structure inquiry and occurs in several sequential phases. A learning cycle moves children through a scientific investigation by encouraging them first to explore materials, then construct a concept, and finally apply or extend the concept to other situations. Let's begin by examining three phases of the learning cycle: (1) exploration, (2) concept development, and (3) expansion.

Exploration

If you are familiar with the learning cycle and before reading further, prepare two lists: one titled "Teacher's Responsibilities During Exploration" and one titled "Students' Responsibilities During Exploration." After doing this, compare the two lists before continuing to read. How do your lists compare to the following paragraphs?

The teacher prepares for the exploration by gathering the necessary materials that students will use during activities in which they are exploring objects or events—for example, all equipment needed to conduct experiments. The teacher provides students with procedures, written or oral, to do the activities and questions, charts, tables, or graphs that students use to guide and record their observations. The teacher guides students to do the exploration safely and, perhaps most importantly, ensures that students gather good data. In other words, the teacher checks students' data to see that their experimental results and observations are accurate. A guiding question for teachers to use when checking for good data is the following: "Will students be able to build the science concept when they interpret their data during the next phase?" Ensuring good data does not mean simply telling students that their data are not good and then providing the good data. Rather, students should experience the gathering of good data, so they associate those data with the phenomena, not what the teacher indicates should have happened. This requires interaction with children and helping them collect good data, not doing it for them.

Students' responsibilities during exploration include participating in their group's efforts to gather and record good data, answering any questions provided in the activities, and assimilating the data. Teachers cannot assimilate data for students; students assimilate the data guided by the teacher.

Some learning cycle curricula use an introductory activity called engagement, and treat it as another phase that precedes and introduces the exploration (Trowbridge, Bybee, & Powell, 2004). Examples of engagement are asking a question ("Do plants need light to grow?"), showing a discrepant event, or defining a problem for investigation.

Concept Development

Following the exploration is the concept development phase. Again, before reading about this phase of the learning cycle, what are your understandings of this phase? How are the responsibilities of the teacher and students during concept development different from their responsibilities during the exploration?

Concept development, sometimes labeled explanation (Bybee & Sund, 1990), is a difficult phase to do properly and well. Usually, the teacher leads a scripted discussion designed to engage students physically and mentally in the construction of the science concept central to the learning cycle. That may seem straightforward, but accomplishing it can be quite daunting. Let's examine specific, necessary events of this phase beginning with the scripted discussion. The script for the class discussion may be a set of scaffolding questions crafted to (1) use all of the students' data; (2) assemble the collective data into a class chart, graph, or summary; (3) guide students to interpret their collective data; (4) disequilibrate students as they search for trends or meaning in their data, if they haven't disequilibrated previously; (5) allow students to accommodate the new science concept (reequilibrate) or, stated differently, understand the new science concept; and (6) introduce the scientific terminology associated with the concept.

A common trap at this point in learning cycle science is telling students the concept; doing so accomplishes little. A teacher cannot accommodate the concept for students, but through questioning, teachers can help students construct meaning of the concept from their experiences, observations, and data. We gathered some data related to this tenet (Marek & Cavallo, 1995). Elementary school teachers of grades K-5 in urban, suburban, and rural settings were observed from across Oklahoma. All of the teachers participating in the study were doing inquiry science on a regular basis. A popular learning cycle that was part of our investigation was about the concept, "plants will sprout and grow from seeds that are put into soil and watered." Student-groups planted beans in pots, watered them when necessary, and kept them near light sources. They made daily observations, recorded when beans sprouted, and charted the daily growth of their plants. After all of the plants had matured, teachers began the concept development phase.

We discovered two groups of teachers when we observed them doing the plant-growing learning cycle in their classrooms. One group of teachers used all of the students' charts and plants when leading their students to develop the concept. The other group of teachers obviously did not understand the concept development phase of the learning cycle. Although their students grew plants and kept good records (either drawings, charts, or both), when it came time to develop the concept, this group of teachers instructed their students to put away their plants and observations because "I will tell you the concept [and] I will tell you about plant growth."

What do you think students of the second group of teachers learned about doing experiments in science? Did these students' gain understandings about plant growth or did they hold misunderstandings after their teachers told them about plant growth? The answer is probably already known without referring to the Marek and Cavallo (1995) study in the *JESE*. A teacher cannot accommodate the concept for students; students construct meaning of a concept from their experiences, observations, and data. Again, concept development is a difficult phase to do properly and well. At the conclusion of the concept development phase, the expansion phase begins.

Expansion

Although the concept development phase may be the most difficult for teachers, research has shown that the expansion phase is often the most misunderstood by preservice elementary school teachers (Marek, Laubach, & Pedersen, 2003). Expansion is not an occasion to introduce new concepts or concepts unknown to students. It is a phase of the learning cycle designed to encourage students to apply their newly learned concept to different situations. The expansion may be additional laboratory or field experiments, it may be working-related problems, or it may be reading information related to the concept in a textbook. During the expansion, it is important that teachers encourage students to use the scientific terminology associated with the concept. In fact, expansion activities may appear very much like exploration activities except that in expansion, students understand (or should understand) the concept central to the learning cycle and are using the scientific terminology. For those students not yet understanding the concept, the expansion phase may provide the opportunity to develop the desired understanding.

Although the expansion may take various forms, it should always be an application of the newly learned concept and an opportunity for students to cognitively organize their new concept with other concepts already known to them. You may know this phase as elaboration, extension, or application. Any of the terms aptly reflect the main purpose of the expansion phase of the learning cycle.

We have examined three phases of the learning cycle. An important, subsequent consideration is evaluation. When do you assess what your students learn from a learning cycle, and what do you evaluate? Addressing the second part of that question ("What do you evaluate?"), evaluate students' understandings of science concepts (conceptual knowledge) and the process skills (procedural knowledge) used during the learning cycle activities. Stated differently, assess what students know (content) and how well they experiment; gather, record, and interpret data; and participate in group and class discussions. Regarding the question about "When do you assess what your students learn?," evaluation is appropriate in one or more phases of the learning cycle, or after the learning cycle is completed. Evaluation is an essential part of the inquiry process and can occur before, during, and/or after the learning cycle, but is evaluation another phase of learning cycles?

3E or 5E Learning Cycle?

The three-phase learning cycle—exploration, concept development, and expansion—was derived from Piaget's model of mental functioning (i.e., assimilation, disequilibration, accommodation, and organization). (The derived association is often attributed to Karplus & Thier, 1967, but for a more complete history and evolution of the learning cycle and its phases, see Lawson, 1995.)

The first phase of the learning cycle, exploration, is designed to cause students to assimilate data and eventually reach a state of disequilibration. In other words, students gather data, look for trends or relationships in the data, and, from this, they become disequilibrated. The next phase, concept development, is structured to lead students through the interpretation of their data, construction of the concept, and accommodation to the concept, which results in reequilibration. The expansion phase is designed to give students opportunities to organize their newly learned concept with other concepts they already know. Relationships between mental functioning and learning cycle phases can be seen in Table 1 (Marek & Cavallo, 1997).

Table 1. Mental Functioning and the Phases of the Learning Cycle

Mental Functioning	Learning Cycle Phases
Assimilation → Disequilibration	Exploration
Accommodation (Reequilibration)	Concept Development (Explanation)
Organization	Expansion (Extension)

So where do engagement and evaluation fit? Although not derived from Piaget's model of mental functioning, engagement and evaluation are useful and, in fact, essential activities when doing learning cycles. My concept of the learning cycle links engagement to the exploration phase and serves as an introduction. Evaluation, in my concept, is linked throughout the learning cycle. In other words, evaluation may be during or after the exploration, concept development, or expansion phases, or evaluation may occur after the leaning cycle is completed. Formative evaluation should occur during the entire cycle. Formative evaluation is essential for teachers to ask the key questions that will encourage assimilation, disequilibration, reequilibration, accommodation, and organization.

Let's apply the 5 Es of the three-phase learning cycle to a concept from mathematics. The next section is the engagement of the exploration, followed by concept development (explanation), and finally by expansion. After you have completed the learning cycle, answer this question: "What would you evaluate if you had your students do this learning cycle?" When you finish this cycle, consider how well you understood the concept (this is not the same as knowing the concept's name) prior to beginning the learning cycle.

A Learning Cycle: What Can You Measure on a Circle?

Engage the exploration by asking, "What can you measure on a circle?" You can measure the distance around the outside (perimeter) of a circle, which is the circumference. You can measure the diameter, which is the distance from one side of a circle to the other and passing through the center point. Measure these two parts of several round objects and record your observations on a chart with three labeled columns: (1) Objects, (2) Circumferences, and (3) Diameters.

We begin concept development by examining the values in your chart, which are your data. If other groups or individuals measured and recorded circles, compare the data in all of the charts. What trends in the data do you observe? What do you notice about the sizes of the circumferences and the sizes of the diameters? Table 2 lists sample measurements and typical data that students gather from this exploration.

Table 2. Measurements of Circles of Different Sizes

Objects	Circumferences	Diameters
Dish	36.0 cm	11.2 cm
Coin	13.5 cm	4.1 cm
Clock	97.0 cm	31.0 cm
Lid	23.2 cm	7.5 cm
Total	**169.7 cm**	**53.8 cm**

The circumferences always have larger values than the diameters regardless of the sizes of the circles. The circumferences are about three times longer than the diameters. Calculate the circumference-to-diameter measurement for the dish (36 cm/11.2 cm = 3.2). All of the circles have this approximate 3:1 circumference-to-diameter ratio. Calculate all of the circumference-to-diameter ratios in your data chart. Are all of these values a little more than three? Do you know the numerical value of this constant? This value is a constant (same for all circles) and is approximately 3.14. It is known as Pi and the symbol for Pi is "π." The concept for this learning cycle can be written as a statement or as a formula: All circles have circumferences (C) that are approximately three times (3.14 or π) the length of the diameters (d). Stated as a formula, $C = \pi d$.

What are some logical activities for the expansion (extension) phase of this learning cycle? Working problems that apply the concept is an appropriate expansion. Solve the following two problems: (1) Our moon's diameter is 3,476 km. Use the formula from the concept development and calculate the moon's circumference; and (2) The Earth's circumference is approximately 40,000 km.

Calculate the Earth's diameter. Another means to expand a concept is through readings. The following is information to begin a "readings" expansion:

> As the idea that the Earth was round became accepted in Ancient Greece, attempts were made to estimate the Earth's size. Perhaps the best of the early measurements of the Earth's circumference was made by Eratosthenes (276-194 BC). He calculated the Earth's circumference to be 250,000 stadia. What is/are stadia? How did he make his calculations? Use your textbooks or the Internet to answer these questions and learn the rest of the story about early measures of the earth's circumference and diameter.

The previous learning cycle could also include an expansion designed to encourage students to figure out a way to derive the area of a circle. Perhaps this would be a means to evaluate students' application of the "π" concept. What other ways and concepts would you evaluate following your students' completion of this learning cycle?

Why the Learning Cycle?

I found the question, "Why the learning cycle?," engaging. In fact, that question prompted me to commence an exploration of "Why the learning cycle?" You just completed reading the data I gathered in my exploration: descriptions of the learning cycle phases, the three phases and the 5 Es, and an example of a learning cycle from mathematics. My explanation (concept) developed through my learning cycle approach to the question "Why the learning cycle?" is because the learning cycle is theory-based and it works, and my expansion activities for the concept (because the theory-based learning cycle works) are readings—recent articles that I recommend to you. These articles describe examples of successful learning cycles in science (Birgit & Lawson, 1999; Engelhardt, Gray, & Rebello, 2004; Escalada, Rebello, & Zollman, 2004; Maier & Marek, 2005). Countless other examples of successful learning cycle science can be found in the literature dating back for decades. A recent article in *Science & Children* (Brown & Abell, 2007) summarizes articles spanning 40 years and concludes this about the learning cycle: "Thus, a learning cycle approach helps students make sense of scientific ideas, improve their scientific reasoning, and increase their engagement in science class." I invite you to explore those articles and others and develop your explanation (concept) for "Why the learning cycle?"

Epilogue

At the Association for Science Teacher Education conference in Nashville a few years ago, I had the pleasure of being on a panel that included Ann Cavallo, Tony Lawson, and Charlie Barman. Our topic was, "Preserving Our Intellectual History: A Panel Discussion of the History and Development of the Learning Cycle." We each had an opportunity to describe our experiences with teaching and researching the learning cycle, which collectively represented many decades! (My apologies to age-sensitive colleagues.) Then the panel took questions from the large group of science educators in attendance. The panel presentation was one of the most gratifying discussions for me and one question in particular stood out: "Why the learning cycle?" We each enjoyed the opportunity to address this question, but Tony Lawson answered it best when he simply said, "Because it works."

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