DARWIN'S NATURAL SELECTION WORKS THROUGH THE LEARNING SPIRAL

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Teaching science requires a combination of effective methods of delivery and the understanding of the knowledge or content of the lesson. When a teacher knows how to teach, but has a poor understanding of the knowledge of the subject, the impact of the lesson is decreased. Similarly, when the teacher knows the content knowledge, but has poor teaching strategies, the lesson is equally weakened. After studying an established model of science instruction based on the application of the learning cycle, for the purpose of improvement, this learning cycle is adjusted and a new model, the learning spiral, is proposed. The method and content we teach evolve over time. Why? Because the learning environment changes over time to include the explosion of knowledge and the ever-changing needs of the society and the learner population. Interestingly, one hundred and fifty years ago, Charles Darwin studied the change of the natural environment and its impact on live organisms to propose the theory of evolution. Two experiments follow which investigate the forces of natural selection by applying the framework of the learning spiral. The experiments illustrate the progressive nature of our understanding of the natural world and the method that we use to teach the concept of natural selection.

The Learning Cycle

The learning cycle is a science education strategy consistent with a number of contemporary learning theories that underscore the importance of learning by experience. An early concept of learning by experience can be traced back to 450 B.C. when Confucius, a Chinese philosopher, explained that learning by doing is more effective than learning by hearing or seeing, “Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand.” In 1938, experiential learning was advocated by pointing out the close relationship between the process of experience and education. Through time, the experience component of education evolved to become more specific. In the golden age of science curriculum development, a prototype called the learning cycle (3E model) was developed with exploration, invention, and discovery phases. The 3E Learning Model was used later in the development of the Science Curriculum Improvement Study (SCIS), an elementary science curriculum. In 1984, an education theorist published a book in which he stated, “Immediate personal experience is the focal point for learning; giving life, texture, and subjective meaning to abstract concepts and at the same time provide [sic] concrete, publicly shared reference point for testing the implications and validity of ideas created during the learning process.” Later, the concept of experiential learning was accepted by academics, teachers, managers, and trainers as an understanding to explain human learning behavior. Experiential learning is facilitated learning using direct experience and is different from academic learning in which learning is achieved through the study of a subject without the connection to any direct experience.

In 2002, the Biological Sciences Curriculum Study 5E Model was introduced; it includes engagement, exploration, explanation, elaboration, and evaluation phases. Two more phases—elicit and extension—were added in 2005 resulting in the 7E Model. In 2009, guides were given to improve inquiry-based instruction by dividing it into sections/levels and stressing assessment at all levels.

Learning is complex in that it is a continuous non-linear process. Nevertheless, the model of learning which divides experiential learning into stages helps us better understand the application of the process. The essence of the learning cycle includes five basic overlapping stages: engagement, exploration, explanation, elaboration, and evaluation. In engagement, the teacher mentally engages students to what their interests and curiosities about a problem or an issue. Engagement invites students to learning. In exploration, the teacher encourages the students to explore ideas and establish experience bases. In explanation, the teacher solicits explanations from the students to reinforce understanding based on established prior knowledge. In elaboration, the teacher challenges students to apply their conceptual understandings to different situations and to make meaningful connections and transitions. Finally, evaluation invites students to assess their learnings and provides opportunities for teachers to evaluate student achievements of established educational objectives. The five stages of the learning cycle are graphically described in Figure 1.

The learning cycle influences classroom practices and textbook design in science education in many ways. When science textbooks present the format of a science lesson, the learning cycle has been referenced as a mode. One science education textbook says, “The activity portion of the text follows the 5-E model of instruction . . . . This learning cycle model reflects the National Science Education Standards (NSES), Science as Inquiry Standards, seamlessly integrating inquiry and the standards to create a science teaching framework best suited for engaging students in purposeful science learning while providing accountability opportunities for teachers.” Other textbook publishers apply the learning cycle to develop lessons stressing that the cycle is what scientific inquiry should be. Some colleges use the five Es of the learning cycle as a lesson planning template and a model of inquiry-based instruction. Chances are that you already may use parts of the
learning cycle when your students are actively solving problems and achieving inquiry-based learning.

Issues of the Learning Cycle

What are some issues that you, as a science teacher, may face when implementing the learning cycle with your students? The four general issues are:

1. The obscurity of students’ misconceptions and what they bring to learning;
2. The less than strategic placement of learning evaluation in the process;
3. The cyclic nature of the model; and
4. The two dimensionality of the cycle.

Where do we appropriately address students’ misconceptions in learning and, hence, in the learning cycle? A student may come to class with an established preconception of a concept. Unfortunately, some of the preconceptions are also misconceptions. These misconceptions, if not clarified and corrected, will interfere greatly with new learning. When was the last time you heard students say that it is hot in the summer because Earth is closer to the sun? How do we proceed to teach the four seasons if students are reluctant to give up their prior misconceived knowledge? The effective teacher will need to offer an alternative hypothesis to stimulate the students’ curiosities, to invite the students to question the accuracy of prior knowledge, to encourage the students to explore better explanations for the issue at hand, or to introduce a discrepant event. How often have we heard students explain that the mass of a tree comes from the absorption of water and nutrients from the soil? How is this misconception interfering with the teaching of photosynthesis? Effective teaching should be powerful enough to dislodge misconceptions and should be done at the beginning of the learning cycle distinct from the engagement stage. A study confirmed that students whose teachers addressed and corrected misconceptions, achieved and maintained higher long-term learning gains. Misconceptions should be elicited or drawn out for examination and clarification. For this reason, an elicitation stage should follow closely after engagement.

In the learning cycle, evaluation is placed at the end as a summative assessment. Nevertheless, this evaluation process can be reinforced by the addition of continuous formative assessments, thus connecting all stages of the learning cycle. A teacher in the engagement phase found out that students had marginal understandings of some prerequisite knowledge. This formative student assessment discovery prompted the teacher to revisit an old concept and to hold back the next stage of exploration for the time being. The adjustment of teaching strategies is guided continuously by the formative assessments of the teacher, otherwise known as fine-tuning or checking for understanding. In this way, assessment informs instruction and needs to permeate the stages of the cycle.

The circular nature of the learning cycle cannot be taken literally for the simple reason that the last stage of evaluation logically does not go right back to engagement at the very beginning. If the meaning of the cycle is taken literally, learning will keep going round and round, never reaching a destination. When learning is taken as a journey, then the circular path needs to be reconfigured to show a distinct beginning and a distinct finish. Successful learning transfer can be the designated exit of the cycle. Interestingly, if the circular path were flat and continuous, it would be impossible to designate an exit. The problematic, two-dimensionality of the learning cycle is logically the next issue of the discussion. Many teachers believe that the learning cycle is a form of scaffolding. The building of a physical scaffold depends on the meticulous layering of the structure. A new layer of learning is built on the structure of a previous layer and so on. If building knowledge is compared to the building of a scaffold, then the learning cycle no longer will be flat or two-dimensional. Instead, the learning cycle will become a three-dimensional, circular structure, like a spiral going up. The building of a structure going up also implies an increase in potential energy as defined by the new, higher position gained. Learning with a higher potential energy has a better chance to make connections to other areas of learning. The expression of saying that teachers bring students to new heights of achievement may be offered to explain literally the three-dimensionality of learning.

From Learning Cycle to Learning Spiral

In view of the four issues of the learning cycle discussed, suggestions to improve the obscurity of handling student misconceptions should address the fol-
lowing: the placement of evaluation at the end of the cycle, the circular path of the cycle with no apparent exit, and the challenging interpretation of the two-dimensional cycle. First, an elicitation phase is added to the cycle; second, the evaluation process is made continuous; third, the learning transfer is designated as the exit point of the cycle; and fourth, the cycle is reconfigured in a three-dimensional structure. All the suggestions for improvement point to the development of a revised learning cycle called a learning spiral. (See Figure 2.)

![Figure 2. The learning spiral](image)

**Using the Learning Spiral in Lesson Planning**

Let us walk through a biology lesson to see how the different stages of the learning spiral are integrated. This lesson is designed for middle school and early high school levels. In the era of standards driven teaching, the first task we need to take care of is the alignment of the lesson to the state goals, the Indiana core standards in science. Teachers from other states easily can align the lesson to respective state goals and standards. The lesson, though simple in nature, tightly integrates the knowledge and skills of the two selected Indiana core science standards to stress the point that an effective lesson seldom is taught in isolation of any single standard.

**Indiana Core Science Standards Alignment**

Grade 8 Core Science Standards are selected to show the alignment of the standards to the lesson and the two experiments. A description of Core Standards 1 and 5 follow.

**Grade 8 Core Standard 1 (Nature of Science)**

Critically evaluate data from a simple experiment and form a logical statement about the cause-and-effect relationship. Compare this information against prevailing theories. Identify when further studies of the question being investigated may be necessary.

**Grade 8 Core Standard 5 (Life Science)**

Differentiate between traits that are acquired and those that are inherited. Explain how a particular environment selects for traits that increase survival and production of offspring by individuals bearing those traits. Explain how not all traits that are selected for are necessarily beneficial for long-term survival of the species.

**Applying the 6Es of the Learning Spiral**

Teachers who are already familiar with the five Es of the learning cycle will have no problems accommodating, with only minor adjustments, the six Es of the learning spiral. Let us examine how the six Es are applied to teaching an evolution lesson focusing on the forces of natural selection.

**Engagement**

The purpose of engagement is to invite the interest of the students. This is the appetizer before the entrée. The use of discrepant events and issue-oriented problems are appropriate to engage students and motivate them to learn more. The teacher conducts the class in a brief discussion about the concept of evolutionary fitness of an organism. The teacher asks for the best indicator of an organism’s evolutionary fitness and offers the class four options. The first option is a person who is killed in an auto accident at age 45 and has five children. The second option is a person who lives to the age of 105 and has two children. The third option is a rich movie star with three children from three spouses. The fourth option is a person who lives to the age of 110 and has no children. A novice to the theory of evolution initially takes the age of a person to determine his evolutionary fitness. How do students know which of the four possibilities is the correct answer? An important note for the teacher to make during a discussion of this nature is to consider the reasons for the students’ answers and remember not to give out the correct answer before doing the two experiments. At the end of the discussion, students should be interested to find out more.

**Elicitation**

One student explains, “The fitness of an organism is the length of his life span.” Another student says, “Fitness means long life.” This obviously is only 50% correct in a sense that a person needs to live and to sustain life. Knowing that some students have misconceptions about the evolutionary fitness concept, the teacher asks how it is successful for a person to live a long life but with no continu-
ation for the family. It is important to know that misconceptions have a tendency to turn off potential positive experiences down the road. Oftentimes when the pieces do not fit together, the teacher must help the students to break down old ideas and reconstruct them.

**Exploration**

At this point, the teacher introduces two simulation experiments. The first experiment investigates how panches (a species of bird) in 2009 survive through natural selection. The second experiment investigates how panches in 2009 thrive through continuous natural selection. A description of the experiments follows.

### EXPERIMENT ONE

**Title**
How do panches survive in Pacific Paradise Island?

**Scenario and background**
Pacific Paradise is an island in the Pacific Ocean. The year is 2009. Red seed plants are the major vegetation on the island and panches are the predominant birds feeding on the red seeds. Panches have several variations. The variations are shapes of the bird beaks. To survive, panches have to eat 30 red seeds per minute during feeding. The rate of 30 red seeds per minute is the survival value. Panches that eat 30 red seeds per minute will survive; panches that eat less than 30 per minute will perish. (Note to the teacher: The survival value is determined arbitrarily by the teacher to discriminate birds to survive or to perish. Teachers in a pre-run experiment can determine best what the optimum survival value is for the experiment so some birds will survive - to continue with experiment two - and some will not.)

**Materials**
Red bean seeds (other seed substitution is acceptable as long as the seed is about two mm in diameter), instruments (representing bird beaks) that can open and close (i.e.; pliers, staple remover, tongs, wrenches, ...) (See Figure 3.), paper cups, pie pans, timers, and sticky-backed labels.

![Figure 3. Instruments for bird beaks](image)

![Figure 4. The test station](image)

**Procedure (for teacher) (See Figure 4.)**

1. Set up test stations; each has a paper cup, a pie pan, and a timer.
2. Place a handful of red bean seeds in each pie pan.
3. Secure five picking instruments that can open and close. Label the instruments A, B, C, D, and E individually with a sticky-backed label.
4. Place one instrument at each test station.
5. Prepare data sheets and place one at each test station.
6. Have students practice using the instrument (representing a variation of bird beaks) to pick up the red bean seeds, drop them in the empty cup, and return them to the pie pan at each station.
7. Rotate students through each test station. The student at each station is to use the instrument for one minute to pick up seeds and drop them in the cup. After one minute, the number of seeds in the cup is counted and recorded in the data report. Place the red beans back in the pie pan each time.
8. The task is complete when the data report at each station is done by all the students. (Note to the teacher: the number of trials can vary. Three to six trials are recommended.)
9. Ask students to go to the board or the computer to compile the individual data to form the group report. (Note to the teacher: If computerized data are used, one can integrate the use of Microsoft EXCEL to generate the group report. With computerized data, students can see the average of the trials the instant the data are completed.)

**Discussion**

1. Which bird(s) (i.e.; A, B, C, D, and E) survived through time (i.e.; all of the trials)?
2. What is the main reason for the bird(s) to live?
3. What happens to the bird(s) which did not meet the survival value? Please explain.
4. What happens to the bird(s) which met the survival value? Please explain.
5. What happens to the bird(s) which exceeded the survival value? Please explain.

**Table I. Panches individual data report**

<table>
<thead>
<tr>
<th>tool letter</th>
<th>seeds picked per minute</th>
<th>average seeds picked per minute</th>
<th>survival value; seeds picked per min.</th>
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tive assessment when the question, “How do students interpret the individual and group data?” is explored. Do students offer the correct answers for the right reasons or wrong reasons? Are students expressing personal opinions or facts with appropriate data support? Ask students to compare and contrast the red and white seeds, the survival tools, and.

Explanation

At the completion of the two simulation experiments, students began to see the change pattern (i.e., evolutionary trend) of panches over one thousand years. That pattern includes which panches (with reference to the beak variation) survived in 2009 and which panches continued to thrive in 3009. Students should be able to explain that a few panches that survived in 2009 (the first experiment) are seen again in 3009 (the second experiment). Obviously, the successful panches have to breed to sustain the species over time. Students based their explanations on the information from the data reports. One student explained beautifully in his own words that if a species of organism is to be successful, enough members of that species have to stay alive (or survive) and flourish (or thrive) by successful reproduction. In other words, the successful species needs to survive and thrive through time. That, said the student, is what evolution is about! Another student added that the shaping force of evolution can be the environment to include such factors as climate and food (e.g.; red seeds and white seeds). The teacher formally introduced the term natural selection as the major force shaping evolution. At this point of the lesson, the teacher clearly saw the learning impact of active student experiential learning.

Elaboration

The teacher extended the lesson of evolution in another enrichment discussion. The discussion compared natural selection and artificial selection. In Japan, samurai (Samurai was an ancient Japanese warrior.) crabs have been found in the inland seas for eight hundred years. The crab appears to have a unique face imprint of an ancient samurai warrior on the carapace or the back. [See Figure 5.] Is the face pattern of the samurai crab inherited? Is the samurai crab a product of natural selection? Through further independent study, students found that samurai crabs are not eaten in Japan but are thrown back into the sea by fishermen because of superstition. When samurai crabs are caught but not eaten, they have a better chance to survive with the potential to produce other crabs. Several students commented after the independent investigation that the prosperity of the samurai crabs is done by the selection (not eaten and thrown back into the sea) of fishermen which is quite different from the selection by nature (i.e.; natural selection). During the discussion, the teacher reinforced the concept that organisms less suited to the environment are less likely to survive and less likely to reproduce while organisms more suited to the environment are more likely to survive and more likely to reproduce. Furthermore, the organisms that survive are most likely to leave their inheritable traits to future generations. Students assessed the understanding of the concept. The new knowledge learned became familiar knowledge where the learning spiral reached the ready stage of learning transfer.

Evaluation

Evaluation is an ongoing process that allows the teacher to determine if the learner has attained understanding of concepts and knowledge. Evaluation and assessment need to occur at all points along the continuum of learning and already are embedded in the experiments described.

Closure

The learning spiral invites learners to the exciting, investigative experience and helps them achieve elevated heights of achievements. As teachers, we need to remember that based in the cognitive learning principle of assimilation, the learning spiral implies that learning cannot be imposed on the learner. Instead, the learner, beginning with a curiosity to learn and then moving to conception and internalization, develops knowledge or skills progressively. Let learning be student-centered. Give students the experience to engage, elicit, explore, explain, elaborate, and self-evaluate their own learnings. Use the learning spiral and take your students to new levels of academic success.

For more information, contact the author by email at <awong@ben.edu>.

References


PORTFOLIOS CAN IMPROVE STUDENT AND TEACHER SKILLS IN SCIENCE

Reena Markstahler
Southwood High School
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This article appeared on pages 15-16 in the Fall 2009 issue of The Hoosier Science Teacher (THST). The author was inadvertently listed as Jane Hunn; Jane did not write the article. It is reprinted here.

Two things I want students to leave with at the end of the year are a skill for organization and a sense of responsibility. We all know how challenging that accomplishment can be for ninth graders, especially if they are not taught the given methodology. Sometimes I overlook the basic skills that I think students should know: how to study for tests, calculate grades, and organize work. By overlooking these skills, I become frustrated with my students’ scores, the lack of homework being turned in, and notes that can not be found because they are stuffed in textbooks.