The Learning Cycle: A Reintroduction

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The learning cycle is an inquiry approach to instruction that continues to demonstrate significant effectiveness in the classroom. Rooted in Piaget’s theory of intellectual development, learning cycles provide a structured means for students to construct concepts from direct experiences with science phenomena. Learning cycles have been the subject of numerous articles in science practitioner periodicals as well as the focus of much research in science education journals. This paper reintroduces the learning cycle by giving a brief description, followed by an example suitable for a range of physics classrooms.

The development of the learning cycle dates back to the work of Atkin and Karplus in 1962. Papers discussing the use of learning cycles can be found in The Physics Teacher and the American Journal of Physics. The most thorough of these deals with the use of learning cycles for large-enrollment courses. More recent articles suggest applications of the learning cycle for classrooms ranging from conceptual to calculus-based physics but do not offer details of its theory base. This paper serves to reintroduce the time-tested inquiry approach to science known as the learning cycle.

Learning cycles consist of three distinct phases: exploration, concept development, and concept application. The phases and the order of the phases were derived from the mental processes individuals engage in as learning occurs. A brief description will be outlined here, followed by an example.

Learning cycles begin with an exploration where students are charged with collecting data. This phase has always been called the “exploration,” beginning with Karplus et al. Explorations can be done in the form of open or guided inquiry, in small or large groups, or as an entire class. However, the exploration must result in “good” data that were gathered by the students. The design of the exploration must be constructed so that reproducible data ensure that students will be armed with the evidence required to derive the concept. Data collected must also be free of “noise” that would require students to know the concept a priori in order to elicit data relevant to the concept to be developed in the next phase.

Ideal explorations are designed to reveal something unexpected to students, causing them to think about how the data or experience they encountered fit with what they already know. If a student can account for the data based on prior knowledge or if the experience was not unexpected after all, assimilation has occurred. During assimilation, observations or experiences are accounted for by students’ existing knowledge. A failed attempt at reconciling the unexpected results or observations with what one already knows is termed “disequilibrium” by Piaget.

Because students have varying experiences and knowledge bases, it is unrealistic to expect collective assimilation or collective disequilibrium in the classroom. Furthermore, some students may have assimilated the experiences based on alternative understandings. That is, students may arrive at correct expectations based on false premises. For these reasons, assimilation and disequilibrium will occur among different students simultaneously during the exploration.
Following the exploration is the concept development phase, when students analyze and interpret the newly collected data. Usually this is in the form of a whole class discussion or group discussions. Although this phase of the learning cycle is more teacher-centered, it should not take on the form of a lecture. Instead, students are guided by the teacher in a discussion designed to let them interpret the class data. Students arrange and report their group data so that they can formulate hypotheses for the phenomenon under examination. As students develop the science concept from their data, they re-equilibrate. Piaget termed this mental process “accommodation.” The second phase of the learning cycle is designed to allow students to re-equilibrate and accommodate the new concept. Appropriate scientific terminology is introduced after the development of the concept. This phase was originally called “invention” by Karplus et al. \(^{17}\)

For those students whose assimilations were under false premises, the concept development phase is doubly critical. The analysis of the data collected should reveal a more plausible explanation than other common alternative explanations. This possibility clearly indicates that disequilibrium is not limited to the exploration phase of the learning cycle. Disequilibrium should occur prior to the end of the concept development phase.

The third phase of the learning cycle, known today as concept application, was originally called “discovery.” \(^{18}\) It should not be assumed that once students have collected the data and developed the concept that learning is complete. According to Piagetian theory, there is more required on the part of the learner for a full understanding of the concept. In concept application, students must apply the newly accommodated concept in a different setting or context and relate it to held conceptions. Concept application, therefore, offers additional opportunities for students to apply the newly accommodated concept to what they already know. This effectively tests and reinforces students’ understandings of the concept. To summarize, the purpose of concept application is to simultaneously reinforce the concept, validate the newly developed concept, and foster thorough understanding. This process is termed “organization” in Piaget’s theory of intellectual development. \(^{19,20}\)

### Circles & Bubbles: A Learning Cycle

Here we briefly describe a learning cycle that is appropriate for an introductory nonscience major’s course or general physical science course. The full version of this learning cycle, including the teacher’s guide, is available online and by contacting the authors. \(^{21}\) The concept students develop by the completion of the second phase is the following:

Data following a linear trend are related by a single slope while data of nonlinear trend are not. This means the slope of a graphed nonlinear trend is not constant. Despite the difference, the plots of linear and nonlinear trends can still be used to make predictions.

Establishing the difference between these two types of relationships and understanding some of the implications of those differences are powerful aids for understanding numerous other concepts in physics.

### Exploration

We have divided the exploration for this learning cycle into two parts. In part I, students are asked to make a prediction about how much the circumference of a circle will change if the diameter is doubled, tripled, or quadrupled. They then begin taking measurements of the diameters and circumferences of an assortment of supplied circles. As students collect data the instructor visits with each group and asks questions such as “Can you identify any trends in your data” or “In looking at your data, can you come up with a general rule that applies to all of your data?” The instructor needs to make certain that data are being recorded carefully and accurately. Once all of the data are collected, specific questions lead students to look for a relationship among the diameters and circumferences. As an example, students could be asked to predict what the circumferences would be for circles of diameters different from any of the supplied circles. Generally, it does not take long for students to conclude that the circumference is about three times the length of the diameter, and multiplying the diameter by three is straightforward enough that the predictions are easily done. Recognizing what this factor represents and its role in the linear relationship is not...
critical at this point.

In part II of the exploration, students are provided a stopwatch, an angle indicator, and a water-filled glass tube with an air bubble trapped inside. Students are first asked to record their predictions for how the time will vary for the air bubble to traverse a certain length of the tube as a function of its angle from the horizontal. To prompt discussion among groups, the teacher could simply ask how fast the bubble will move if the tube is lying flat on the table versus held perpendicular to the table. Students then begin recording the time it takes for the trapped air bubble inside the tube to travel a specified distance for several different angles from the horizontal.

Due to the nature of the nonlinear trend, students should collect at least nine pairs of data between $0^\circ$ and $90^\circ$. They should soon realize this trend is not like that of part I; that is, one measurement of a paired data set is not just a simple factor of another. Despite the lack of a linear relationship, students are asked to make time predictions for various angles.

An integral part of the exploration in this learning cycle is graphing the data. Although there is value in having students make predictions from inspecting the raw data, graphs help reveal trends that might not be seen otherwise. Students are asked to draw best-fit curves for parts I and II of the exploration and to compare their predictions to trends of the graphs. This phase of this particular learning cycle also demonstrates the need for continuity of data and the value of graphing data as the best-fit lines confirm or challenge their predictions.

**Concept Development**

A plot of the data from part I of the exploration is obviously different from that of part II (see Figs. 1 and 2, respectively). Determining the slope of the graph from part I is straightforward but meaningless for the bubble data of part II due to its nonlinear nature. Recognizing how data from each part of the exploration can be used to make predictions, while at the same time being confronted with the fact that the two trends are very different, serves as the beginning of the concept development phase during which “why” questions are asked and answered by the students.

By the time the class begins the concept development phase of Circles & Bubbles, students are well prepared for the interpretation of their collective data. The instructor’s role during this phase is to facilitate discussion and guide students as they develop the concept.

Regarding exploration part I, the linear nature of the relationship between a circle’s diameter and circumference can easily be observed by having students...
report the corresponding circumferences for diameters of 4 cm, 8 cm, 12 cm, and then 2 cm, for example. Then students can be asked to make predictions about the circumference of a circle whose diameter falls outside the range of their data. Students should be able to arrive at a solution by multiplying the diameter by a factor of about three or by setting up a proportion based on data already collected—prompted by the questions asked of them moments earlier. Important to the concept is the fact this proportionality holds true for linear trends regardless of the numeric value of the slope.

In contrast, the data for exploration part II yield predictability although they do not follow a simple rule. To demonstrate this, student groups could be asked to estimate the angle for which the bubble will travel the specified distance in the shortest and longest durations of time based on their findings. They could then be asked, if the tube was placed at an angle exactly between these angles, would the time be twice the shortest duration of time? Such questions help students recognize and understand the nonlinear behavior of the data.

As part of the discussion, students should contrast the constant slope of part I’s graph with the varying slope of part II’s graph. After they make the connection between the behavior of the slope and the characteristics of the trends, the terms “linear” and “nonlinear” should be introduced. The descriptions of terminology introduced during the concept development phase must coincide directly with student experiences within the current learning cycle. This does not preclude referring back to previous experiences. Instead, this is a means to avoid “telling” in lieu of “learning” by introducing anachronistic terminology.

To conclude the concept development phase of the learning cycle, a final question should be asked of the students so that they have the opportunity to express in their own words the concept that has been developed. Typically this is in the form of a concept statement. It could also be in the form of a summary of the activity using the appropriate terminology. Student statements or summaries should closely parallel the concept indicated at the beginning of the teacher’s guide of the learning cycle.

**Concept Application**

For the third phase of the learning cycle, students apply the concept to a different context during a student-centered activity. Often the concept application phase of a learning cycle serves as a lead-in for the next learning cycle. For Circles & Bubbles, concept application involves collecting data using toy cars. Each group is provided a car that travels equal distances for equal times (constant speed) and a car that does not (accelerating). The constant speeds and the accelerations need not be identical among student groups. It may be beneficial to have a variety of speeds and accelerations to offer opportunities for students to see the relevance of the newly developed concept to a variety of systems.

The structure of the third phase is variable and can serve as a means of evaluation. For the concept application phase of this learning cycle, students record the position of their two cars as a function of time. Recalling the need for several pairs of data in the exploration, students are instructed to collect as much data as necessary to accurately represent the position of their cars as a function of time. To make this clear, ask students if they can make accurate predictions for specific times or distances based on the data collected. Whiteboards (2-ft-x-4-ft sections of white bathroom wall paneling) and dry erase markers have been used in the past for students to record their data, generate graphs, and answer questions during the concept application phase of this learning cycle. For additional material on questions designed to probe students’ understandings and on the importance of the concept developed in this learning cycle, see the first chapter of *Teaching Introductory Physics* by Arons.

**Comments**

Each learning cycle has at its core a concept for students to develop. This does not mean that learning cycles are limited in depth or level of use. For example, in Circles & Bubbles, students could determine the numerical relationships for each of the data sets using graphing software. If the concept application included an investigation of distance or velocity as a function of time, taking the derivative or integral, respectively, of the mathematical functions representing the trends
would be appropriate for a calculus-based physics course.

With Piagetian theory as its foundation, the learning cycle is a time-tested approach to instruction. The purpose of this paper is to reintroduce the learning cycle by articulating some of the finer details of the three phases of the learning cycle by example, while at the same time stressing the importance and rationale for each.

References
12. See Ref. 10.
17. Ibid.
18. Ibid.
21. Send requests for electronic copies to sjmaier@nwosu.edu or eamarek@ou.edu. Circles & Bubbles can also be downloaded from http://www.ou.edu/education/ilac/science/homepage.htm. Follow the “Current Happenings” link.
22. A. Arons, Teaching Introductory Physics (Wiley, New York, 1997). In particular, see Chap. 1 for the emphasis placed on linear trends and student reasoning of graphs.

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