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ABSTRACT

Originally developed in an elementary science program called the Science Curriculum Improvement Study, the learning cycle (LC) teaching approach involves students in an active learning process modeled on four elements of Jean Piaget's theory of cognitive development: physical experience, referring to the biological growth of the central nervous system; social interaction; physical maturation; and self-regulation, the active process of forming concepts. The LC approach consists of three phases. The first phase is exploration, in which students are engaged in motivating activities that require physical experiences and social interaction to provide a basis for the development of specific concepts. In the second phase, concept introduction, the instructor builds on students' exploratory experiences to introduce the main concepts of the lesson. The final phase, concept application, provides students with an opportunity to study additional examples (. the main concepts or to challenge themselves with new tasks requiring extrapolation from earlier lessons. Implementing the LC requires a shift in educational philosophy from the view of students as empty vessels to be filled with large amounts of information to the use of strategies emulating scientific methodology and incorporating recent cognitive science findings. Flow charts of the LC process, graphs, are included. (Contains 21 references.) (MAB)

The Learning Cycle and College Science Teaching

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Abstract

The Learning Cycle and College Science Teaching

Originally developed in an elementary science program called the Science Curriculum Improvement Study (SCIS), the learning cycle teaching approach involves students in active learning by virtue of three phases. The first phase, exploration, involves students in hands-on manipulation of materials and ideas to provide common cognitive experiences, to raise questions, and to promote cognitive dissonance. The second phase, concept introduction, involves the teacher and student in forming one or more concepts that have developed as a result of the exploration experiences. The final phase, concept application, provides an opportunity for students to apply the concept(s) to new situations.

The first part of this paper describes some of the psychological underpinnings of the learning cycle and discusses the basic characteristics of this teaching model. The remainder of this paper provides a rationale for using this model in college science teaching and offers suggestions of how this approach could be incorporated into traditional college science courses.

Introduction

College science courses, especially those at the introductory level, have been characterized as boring and irrelevant to the world of the student. For example, Volpe (1984) had this to say about introductory biology courses: "The agonizing feature of science education today is the wide gulf between one's studies and one's life. The challenge of education in the sciences is to expose students to learning experiences that will make the scientific outlook part of their daily living;...(the) nonscience major is exposed to a highly factual, encyclopedic introductory course in biology..." Even though Volpe is making reference to introductory biology courses, we believe similiar criticisms could be addressed towards other science offerings. For example, several reports, including those from the National Research Council (1990) and Project 2061 (Rutherford and Ahlgren 1990), offer a grim view of the status of science education in the United States. Mix, Farber, and King (1992) summarize these reports by saying: "The overwhelming conclusion derived from these reports is that science courses at all levels have failed to educate students in understanding science, science as a process, scientific thinking, relationships between science and technology and between science and society."

Most science courses are taught with the belief that students are "empty vessels" that need to be filled with large amounts of information. For the most part, this information is merely memorized for a test and then quickly forgotten. We propose teaching science in a more active way. We believe that science teachers should use teaching strategies that emulate the way scientists do science and should incorporate recent findings from the cognitive sciences. One such method of instruction orignially proposed for younger children, is called the learning cycle (Abruscato, 1992). The remainder of this paper describes the basic components and philosophy of this approach, cites research evidence supporting this approach, provides examples of college science lessons that follow the learning cycle format, and suggests ways to implement this method in traditional lecture classes.

Background Pertaining to The Learning Cycle

The learning cycle is a teaching strategy that was first formally used in an elementary science program called the Science Curriculum Improvement Study (SCIS Handbook 1974). Although this strategy was first introduced in an elementary science program, several studies have shown this technique to have widespread applicability to a variety of grade levels, including college (Barman 1992, Barman Cohen and Shedd 1993, Purser and Renner 1983, Saunders and Shepardson 1987, Stepens, Dyche and Beiswenger 1988). The learning cycle is modeled after Jean Piaget's theory of cognitive development (Lawson and Renner 1975). The components of this strategy are designed to include four variables which Piaget and his contempories believe interact during the formation of concepts. These variables include physical experience, social interaction, physical maturation, and self-regulation (Gallagher and Reid 1981). Physical experience is the manipulation of materials, objects, and ideas and social interaction is the dialogue that occurs between individuals when they are discussing an idea.

Physical maturation, in this case, refers to the biological growth of the central nervous system. The time sequence of physical growth varies from person to person and it is this growth that determines how well a person can deal with abstract concepts. According to Piaget and other cognitive theorists, this intellectual growth is chracterized by a series of four invariant stages (Gallagher and Reid 1981). These stages are: (1) sensorimotor, (2) preoperational, (3) concrete operational, and (4) formal operational. The first two stages are generally attributed to early childhood and the first three stages are characterized by the inability to perform abstract thinking. As a person makes the transition from concrete operational to formal operational thinking, he or she begins to think abstractly. This is a gradual process, and a person in transition may be able to do abstract reasoning in some areas, but not in others. Piaget also believed that age was not the only factor attributing to mental maturity. He believed that if a person lacked approprate physical experiences and verbal interaction as a child, this person might not use formal reasoning to deal with specific concepts even as an adult. To understand specific abstract concepts, this person would need to be taught using concrete teaching methods that encouraged appropriate discussion with peers and with the instructor.

A fourth variable for concept formation, self-regulation, is described by Piagetian contempories (Gallagher and Reid 1981) as the active mental process of forming concepts. During this process, mental activity is influenced by the interplay between the person and his or her physical experiences and social interaction. Generally, there are times when a person's ideas seem to fit together, and there are other times that a person witnesses discrepancies in his or her logic. The term equilibration is used by Piaget (Gallagher and Reid 1981) to describe the times when a person's ideas seem to fit together. When presented with new information, if the person's mental activity is in equilibration, the new information will be accepted or assimilated into the person's current conceptual framework regarding a specific concept. If, on the other hand, the person is presented with information that does not fit his or her conceptual framework, the person will experience mental dissonance or disequilibration. At this time, a person is faced with the decision to either disregard the discrepancy or modifiy his or her thinking to deal with this discrepancy. This reconstruction or altering of an existing concept is called accommodation. Figure 1 summarizes the process of self-regulation.

(INSERT FIGURE 1 ABOUT HERE)

The Learning Cycle

Recently, Barman (1990) clarified and modified the SCIS learning cycle. Like the original model, Barman's version consists of three phases: (1) exploration, (2) concept introduction, and (3) concept application (figure 2). During the exploration phase, the students are engaged in solving a problem or task. This challenge is open-ended enough to allow students to follow a variety of strategies yet specific enough to provide some direction. The purpose of this phase is to engage the student in a motivating activity, requiring physical experiences and social interaction, that will provide a basis for the development of a specific concept or concepts and vocabulary pertinent to the concept(s). This phase also provides an excellent opportunity for students to become aware of their personal concepts about specific natural phenomena and for instructors to assist students in questioning their understanding of the natural world as well as help them with misconceptions they may uncover. For example, in a lesson on the major differences between plant and animal cells, the exploration phase might consist of students examining different cells (e.g. onion skin, squamous epithelial, elodea) under the microsope. The students would make drawings of the cells and identify differences and similarities observed in the cells.

(INSERT FIGURE 2 ABOUT HERE)

In the second phase, concept introduction, the instructor gathers information from the students with regard to their exploration experience and uses it to introduce the main concept(s) of the lesson and any vocabulary related to the concept(s). During this phase, the instructor will use appropriate techniques, such as textbooks, audio-visual aids, other written materials, or "mini-lectures" to develop lesson concept(s). Using the cell lesson as an example, the Instructor would have the students report their microscope observations and have them identify specific differences and similarities they observed between the plant and animal cells. The instructor would then use this information to explain the major differences between plant and animal cells. This explanation could be accomplished via a mini-lecture using an overhead projector and it could include a short audio-visual presentation of other plant and animal cells.

The final phase, concept application, is an opportunity for the students to study additional examples of the main concept(s) of the lesson or to be challenged with a new task which can be solved on the basis of the previous exploration activity and concept introduction. In the case of the cell lesson, the students could be presented with preserved slides of additional examples of plant and animal cells. The students would be challenged to identify each cell as plant or animal and explain the reason for their choice.

Evidence for Using the Learning Cycle

Physical experiences and appropriate classroom discussion are an important part of the learning cycle. Yet, it is this component of the learning cycle that might cause college instructors to view this strategy as an inappropriate teaching model for college classes. Most traditional college science courses require students to listen to lectures without an opportunity to discuss this information effectively with one another or the instructor. Research data suggests that the use of hands-on activities and appropriate discussion in college classes is not only appropriate but is essential for concept development. Studies indicate that many college students are less sophisticated in their thinking than previously assumed. These studies also indicate that these students would benefit from more concrete instructional methods, including hands-on activities and appropriate discussion related to these activities. For example, Popejoy and Schweers (Bybee and Sund 1982) used the Burney Test (Burney 1974) to assess the reasoning of 600 college students at a Western university. Their findings indicate that 45% of these students require concrete instructional methods to understand most of the abstract concepts studied as part of their college curriculum.

During the 1992-93 academic year, Allard and Barman assessed the reasoning of introductory science students at a Southwestern college and a Midwestern university, respectively. Both institutions have a large population of non-traditional students and, therefore, over half of the students in these samples were twenty years of age or older. Using the Group Assessment of Logical Thinking test or GALT (Roadrangka, Yeany, and Padilla 1983) with 48 introductory biology students, Allard found that 54% of these students would benefit from concrete instructional methods. Barman administered the GALT to 101 students who were enrolled in a basic science skills course. He found that 72% of these students would benefit from concrete instructional methods.

In studies involving the learning cycle and college science classes, positive gains in student achievement were observed over the traditional lecture/laboratory format. For example, Wilke and Granger (1987) found that the learning cycle increased students' retention rate of biological concepts. Abraham (1989) reported that students exposed to the learning cycle in science instruction performed equally as well on tests as those exposed to traditional methods with regard to some concepts and in relation to other concepts the learning cycle group outperformed those taught with traditional methods. In addition, Stepans, et. al., (1988) found that the learning cycle was more effective in bringing about conceptual change and understanding than was a more traditional lecture approach.

Implementing the Learning Cycle

Although the learning cycle has been incorporated into college science and science methods courses that have previously used a more traditional lecture/laboratory approach (Abraham 1988, Barman 1988, Lawson, Rissing, and Faeth 1990, Stepans, et. al. 1988, Wilke and Granger 1987), it is important to point out that in each instance this transition took time, effort, and a change in teaching philosophy. The learning cycle requires an instructor to be a facilitator of learning and not just a dispenser of knowledge. It demands that the classroom atmosphere is one where the student can explore and test out different ideas.

Implementing the learning cycle also means the elimination of the distinction between lecture and laboratory. Instead, the course instruction needs to be organized into a series of learning cycle lessons. Certain laboratory experiences will be designed to provide meaningful exploration at the beginning of each lesson. The lecture or information sharing will occur as an outgrowth of the exploration phase activities and other laboratory sessions will provide opportunities for students to apply what they have learned in the previous phases to new situations. For example, in a traditional laboratory/lecture course, the topic of biological consumers would be presented by beginning with a lecture that explains the structural differences between herbivores, carnivores, and omnivores. Then, a laboratory exercise would provide opportunities for students to observe different labeled skulls of some common herbivores, carnivores, and omnivores. In other words, using this method, the laboratory experience is considered a supplemental part of the lesson and is primarily used as a verification of what is presented in lecture.

In contrast, laboratory experiences are viewed as an integral part of learning cycle lessons. These experiences are either used in the exploration phase as a vehicle to develop concepts and vocabulary or in the concept application phase as a means to enhance or expand concept development. For example, a learning cycle lesson dealing with biological consumers would begin with an exploration activity in which the students would observe several unlabeled skulls of common herbivores, carnivores, and omnivores. The students would be asked to examine the skulls and look for differences and similarities between them. During the concept introduction phase, the instructor would invite the students to discuss their observations.

Using this information, the instructor would explain how specific adaptations the students observed contribute to the food getting habits of specific organisms. The instructor would introduce the terms herbivore, carnivore, and omnivore and possibly use an audio-visual presentation to enhace the concept introduction. Then, in the concept application phase, the students would be asked to re-examine the skulls from the exploration phase. By examining the teeth and the jaws of each skull, the students would be asked to determine whether the animal is an herbivore, carnivore, or omnivore and explain the rationale for their choices. (Table 1 displays the differences between the learning cycle and a typical lecture/laboratory format as discussed in this section.)

(INSERT TABLE 1 ABOUT HERE)

Conclusion

Probably, the biggest obstacle in implementing the learning cycle in lecture/laboratory classes is the restructuring of class time. To work effectively, learning cycle lessons must be able to flow from one complete lesson to another. Using this format, the sequence of the lesson determines what occurs in each class period rather than having the session dicate whether it is time for a lecture or a lab.

We admit that implementing the learning cycle will not make your teaching easier. In many cases, it will require a major change in the way you deliver your course material. However, we believe that by using this approach you will provide more meaningful instruction to a greater number of your students.

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Figure 1

Self-Regulation

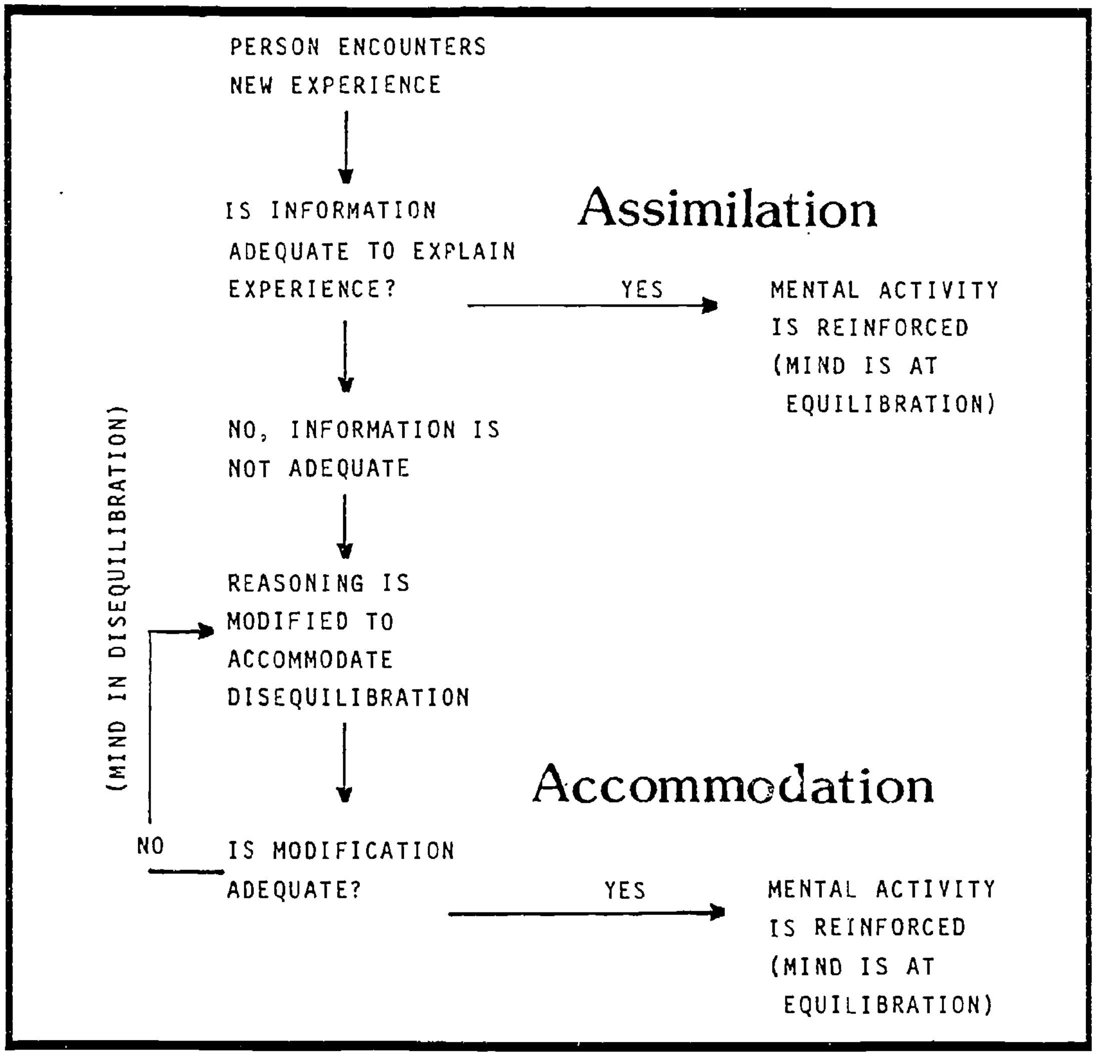
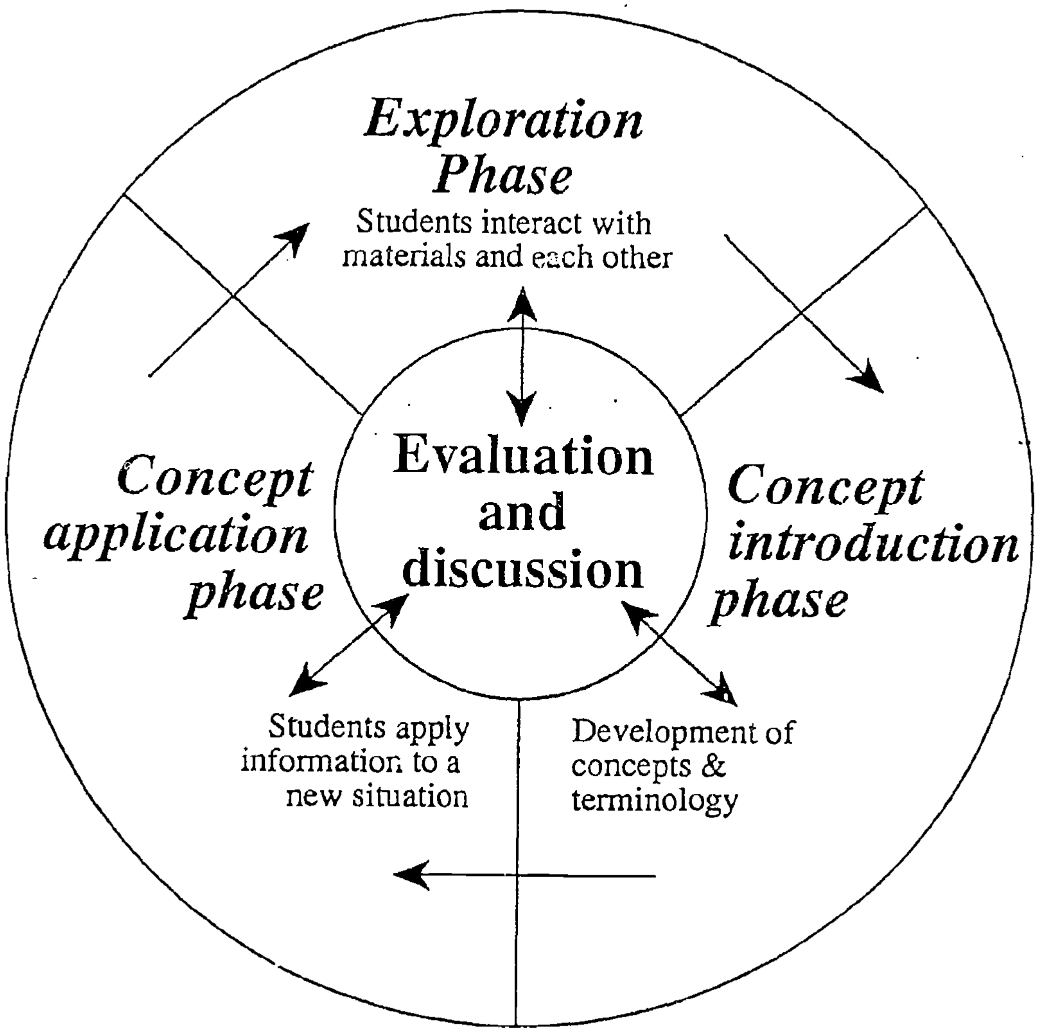


Figure 2

The Learning Cycle



Unidirectional arrows indicate the relationship between the phases of the learning cycle or how one phase leads to the next one. Ideally, the concept application phase of one lesson can lead to the exploration phase of a new lesson. The bidirectional arrows indicate that evaluation and discussion can be integrated into any part of the cycle.

Table 1

Comparison Between a Learning Cycle Lesson and the Lecture/Lab Approach	
Topic - Biological Consumers	
Learning Cycle Format	**Typical Lecture/Lab Format**
Exporation Phase: The students observe unlabeled skulls of common herbivores, carnivores, and omnivores. During their observations, they identify the differences and similarities between the skulls.	**Lecture:** The students listen to a lecture about herbivores, carnivores, and omnivores. The instructor explains the structural differences between the jaws and teeth of these organisms and how these differences relate to the food getting habits of each organism.
Concept Introduction Phase: The students discuss their observations. The instructor relates their observations to the food getting habits of herbivores, carnivores, and onmivores.	**Laboratory Session:** The students examine labeled skulls of common herbivores, carnivores, and omnivores. They are asked to pay special attention to the differences in the jaw structure and dentition of each organism.
Concept Application Phase: The students re-examine the skulls from the exploration phase. They are asked to determine whether the skulls are from an herbivore, carnivore, or an omnivore and explain their reasoning for each selection.	