Designing Biology Laboratory and Field Experiences for Thinking

Anton E. Lawson

The work of researchers including Piaget (1966), Bruner, Goodnow, and Austin (1956), and others studying the development of thinking processes in children and adolescents clearly indicates the need for two things: (1) the opportunity for the learner to do something with the empirical world, and (2) the opportunity to talk, argue, and otherwise reflect on what has been done, what it means, and how it fits or does not fit with previous ways of thinking. Piaget's term for this reflective thinking process is self-regulation.

Biology experiences in the laboratory or in the field can be crucial to the development of thinking abilities and understanding. These experiences should be presented in such a way that they encourage students to actively debate results and reflect upon their implications and explanations; otherwise, they will do little to develop thinking abilities. How then can biology and field experiences be designed to contribute to this important goal?

Some Options

Suppose you were asked to develop a field experience to study the ecology of an intertidal area. Try ranking the following procedures in terms of how you perceive their effectiveness in promoting thinking by your students. Use 1 for most effective and 4 for least effective

A. Provide the students with rulers, and run a transect from the upper to lower zone in the intertidal area. Have students measure and record shell sizes of *Tegula funebralis* snails (a common West Coast snail) found at different locations along the transect. Ask them to plot size versus frequency graphs for the snails measured.
Rank ( )

B. Provide the students with rulers, quadrats, and a map of the intertidal area, and ask them to measure and record *Tegula* shell sizes and to determine the density of the snails from three locations in the intertidal area--the lower, middle and upper zones. Then ask them to search for relationships among the variables and to explain these relationships in light of other observations and general ecological concepts.
Rank ( )

C. Explain to the students that interspecific competition affects population characteristics of many species. For example, the snail *Tegula funebralis* is common in the intertidal area. The older snails (larger ones) are found in the lower zone; the younger snails (smaller ones) live in the upper zone. Tell the students that this is so because their food source (algae) is more abundant in the lower zone; however, the starfish *Pisaster* that preys upon them, lives in the lower zone. Since the smaller snails are unable to move fast enough to escape the starfish, they must remain the in upper zone. Now have your students go the the intertidal area and collect data to verify that what you have explained is correct.
Rank ( )

D. Provide the students with rulers, thermometers, identification keys, quadrats, and a map of the intertidal area, and ask them to select an abundant population in the area, idenfity interesting variables with respect to individual organisms and the population's distribution, and search for relationships among these variables.
Rank ( )

To induce reflective thinking and self-regulation on the part of your

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students an introductory period of exploration or openness is needed. Hence, procedures B and D are the most likely ways to initiate student question asking and self-regulation. Procedure D may be more effective than B for the more capable students because it is more open and allows students an opportunity to examine interesting phenomena that you may not have anticipated. However, this procedure offers little guidance to students; thus it may not be as effective as the somewhat more structured approach in procedure B for the less able or less motivated students. The choice of openness or structure often depends on the reasoning abilities of your students and their past experiences with this kind of instruction.

Procedure A provides students with concrete experience; however, as it is presented it is not likely to initiate self-regulation because it is very directed and uses a "cookbook" approach. Self-regulation could, however, be initiated if the plotted data were used to raise some questions relative to previous partial understandings. Procedure C unfortunately is very similar to the kind of labs and field work many of us frequently conduct. Because the students already know what the data are supposed to show, no self-regulation is likely to occur. This approach encourages a reliance upon authority rather than on evidence and self-initiative.

Designing Biology Experiences for Thinking

How does one go about designing or adapting existing laboratory and field experiences to promote reflective thinking and self-regulation? First, we should be aware that not all things we do in biology call for reflective thinking. For example, we may want students to learn the names of a variety of species of organisms. If so, the identification and memorization of names is required. Or we may want students to learn to use a microscope or a pH meter, or to apply the Winkler method, or the methods of chromatography. Again, if these are our goals, demonstrations, written directions, or self-instructional modules with tapes, slides, and other aids are most appropriate.

Reflective thinking is required whenever we study a natural phenomenon and attempt to discover relationships among variables that can be isolated in that phenomenon. This, of course, is the business of scientists. They describe phenomena and seek relationships among variables (e.g. correlations, proportions, causes and effects, probabilities). They invent explanations based upon their knowledge of the phenomena and their creative abilities. And they seek evidence to support or refute hypotheses wherever such evidence may be found.

The starting point for the development of laboratory or field experiences to provoke thinking must be the teacher's isolation of an interesting phenomenon—an object, event, or situation that students can observe—that is amenable to manipulation or description and that leads to the isolation of specific variables. The behavior of garden snails can be chosen as the phenomenon; temperature, moisture, salinity, light and gravity become the variables to be manipulated. The phenomenon of density of Ponderosa pines relative to the variables of elevation, rainfall, soil type, and temperature is another system that could be investigated. On a field trip, students map the distribution and density of trees over a wide geographical area, measure environmental parameters, search for relationships and attempt to explain these relationships. One further example is the phenomenon of microbial population growth. Specific variables that could be isolated and/or manipulated are nutrients, space, inhibitor chemicals, time, and population size and type.

The steps for successful laboratory and field experiences are these:

1. The teacher must isolate an interesting object, event, or situation that can be observed in the laboratory or field.
2. Students are given an initial period in which they freely explore the object, event, or situation, become familiar with it, raise questions about it, attempt to isolate interesting relationships and relevant variables, and search for patterns or generalizations. Keep in mind that during this exploration phase "slower" students often get bogged down and need special assistance in getting started and in sustaining interesting avenues of investigation.
3. These relationships are then highlighted by the students or by the teacher and often given names (e.g., "food chain" to refer to guppies eating *Daphnia,* that ate algae;" competitive exclusion" to refer to the elimination of one species of *Paramecium* for another when raised in the same container).
4. Students then conduct further investigations with specific variables that have been isolated and seek to test definite relationships among the variables. The teacher may introduce new materials that permit investigation of similar relationship in other contexts.

For example, suppose that after an exploration of the organisms that live in a laboratory aquarium, we have introduced the concept of the ecosystem. Then field investigations of a forest, pond, seashore, river, or meadow would allow for concept reinforcement, refinement, and enlargement and permit students to complete the self-regulation process.

Some Additional Options

As an additional example of how to design experiences that promote thinking and self-regulation, you may wish to consider a number of ways of introducing your students to the physiology of *Daphnia.* Try ranking the following procedures in terms of how you perceive their effectiveness in promoting reflective thinking.

(Concluded on p. 191)

Experiences for Thinking

...from p. 184

Again use 1 for most effective and 4 for least effective.

A. Provide the students with live *Daphnia*, thermometers, depression slides, and compound microscopes. Have the students count the number of heartbeats per minute of the *Daphnia* at three different temperatures; 5, 20 and 35 degrees C. Ask them to plot the number of heartbeats versus the temperature on a sheet of graph paper.

Rank ( )

B. Provide the students with live *Daphnia*, thermometers, despression slides, and compound microscopes, and ask them to find the number of heartbeats per minute. Then ask them to find out if different temperatures influence the rate of heartbeat and to explain how variables could account for the differences observed.

Rank ( )

C. Explain to the students that temperature has a general effect on the metabolism of invertebrates. Higher temperature means a higher rate and lower temperature slows down metabolic activity. One rule states that metabolic rate doubles for every 10 degrees increase in temperature. A cold-blooded animal like *Daphnia* is directly influenced by environmental temperature. Now have your students go to the laboratory and use life *Daphnia* to verify that what you have explained is correct.

Rank ( )

D. Provide students with live *Daphnia*, a hot plate, dexedrin solution, 5% solution of alcohol, a light source, rulers, thermometers, slides, pH paper, balances, graph paper, microscopes, a stirring device, and ice cubes. Ask them to investigate the influence of environmental changes on the heartbeat of *Daphnia*, and to search for quantitative relationships among the variables.

Rank ( )

I would rank the procedures D, B, A, C. Procedure C could provide a good lesson following exploratory activities suggested in procedures D, B, or A. Procedure A or B could serve as an additional laboratory activity about the introduced concept of stimulus-response following the explorations suggested in D.

A positive benefit of the initiation of biology lab and field work with the open exploration of some natural phenomenon is that, in most cases, unexpected events will occur and questions will be raised that cannot be answered by looking in textbooks or lab manuals. Textbooks contain general answers. These experiences pose specific questions—questions that must be answered through "real" inquiries.

References

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Man must choose what is more important—his differences or his similarities. If he chooses the former, he embarks on a path that will, paradoxically, destroy the differences and himself as well. If he chooses the latter, he shows a willingness to meet the responsibilities that go with maturity and conscience. Though heterogeneity is the basic manifestation of nature, as Spencer observed, a still greater manifestation is the ability of nature to create larger areas of homogeneity that act as a sort of rim to the spokes of the human wheel.

Norman Cousins
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