Using the Scientific Method to Study Optical Orientation in Blowfly Larvae

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This introductory lab in beginning biology courses for majors or nonmajors illustrates scientific investigation more realistically than do many textbook treatments of the "scientific method" and many "exercise" type labs. It helps students appreciate that scientific investigation not only involves reasoned conclusions based upon relevant and valid evidence, but also that it is iterative, cooperative, and tentative.

In the first activity, each lab group simulates the scientific process by playing a simplified version of the card game New Eleusis in which a group of "scientists" seeks to determine a "law of nature" (the rule governing a sequence of playing cards) through a series of "experiments" (Gardner, 1977). One lab group member acts as "Mother Nature" and the others act as "scientists." To set up the game, "Mother Nature" devises a relatively simple "secret law" which will govern the sequence of cards which can successfully be played by the "scientists" and writes it on a sheet of paper out of view of the "scientists." For example, the law could be "each card is the same color but a different suit from the previous card." "Mother Nature" selects two cards which obey the written sequencing law and places them face up on the table next to each other. These two cards serve as the "initial observation" made by the "scientists."

The bulk of the game consists of the lab group members then seeking to discover the secret law. The "scientist" on "Mother Nature's" left proposes out loud to the other "scientists" an hypothesis to explain this "initial observation" (i.e., tries to guess what the secret law is). That "scientist" then selects a card of his or her choosing from the deck and gives it to "Mother Nature." This card is thus the scientist's "experiment" or "further observation" to test his hypothesis. Discussion among the "scientists" is encouraged during the choosing of any hypotheses or "experiments." If the card given to "Mother Nature" correctly follows the secret sequence law, then "Mother Nature" places it to the right of the last correct sequence card. If it does not follow the rule, then "Mother Nature" places it beneath the last card played. Play then proceeds to the next "scientist" around the table who either agrees with the previous hypothesis or else modifies it. This "scientist" then performs an "experiment" of his own. Figure 1 shows an example of a card layout generated during a game using a very simple rule. At any stage of the game, the scientists as a group may ask "Mother Nature" if their current hypothesis is correct. If the hypothesis is correct (i.e., it essentially restates the secret rule), then the game is over and the scientists win. Conversely, if the hypothesis is not correct, then the game is over and "Mother Nature" wins.

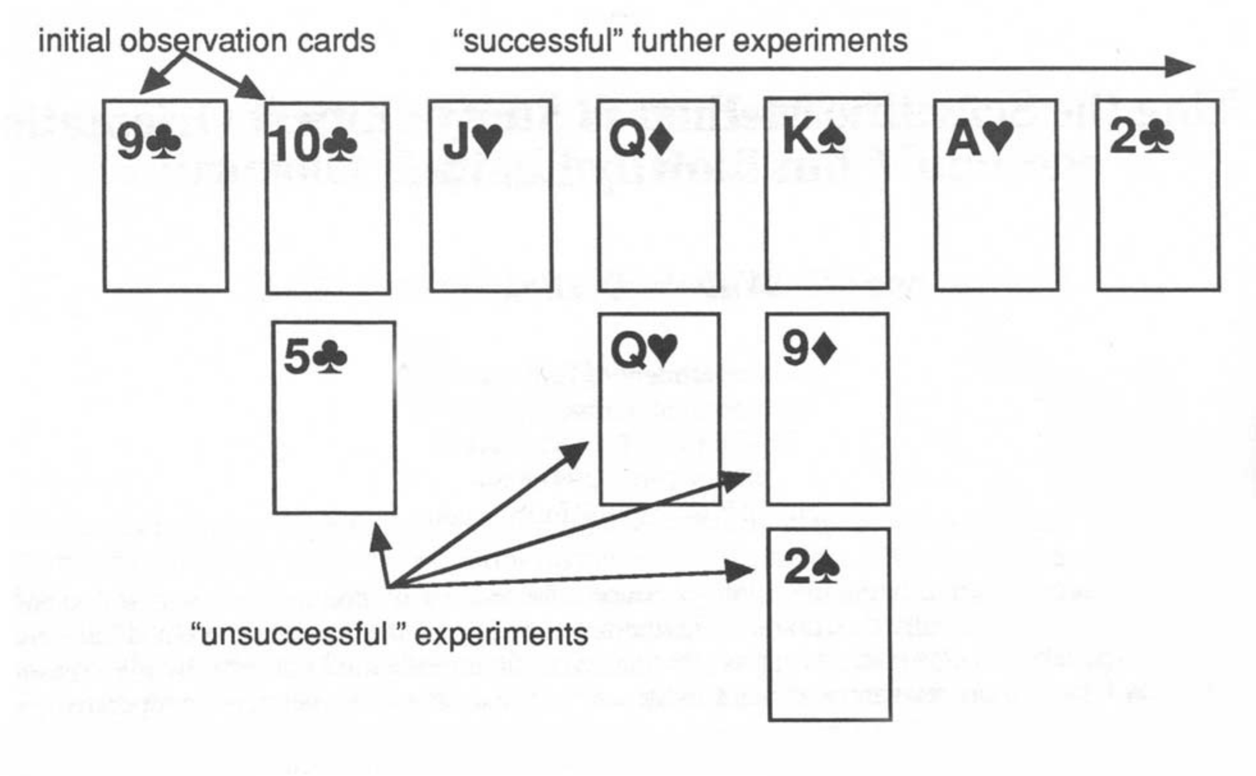

Figure 1. Possible sequence of play when the law is "Each card is one value higher that the previous one."

The game (and "real" science) requires cooperation among the players (experimental results, ideas and new hypotheses are shared), iteration (a single observation or experiment is usually not enough to convince one of the validity of an hypothesis), revision of hypotheses in the face of new evidence (you must modify your hypothesis until it explains all of the relevant data), and the use of "negative experiments" (sometimes playing a card which your hypothesis predicts will be "unsuccessful" is a good additional way to test the hypothesis). Conversely, the main way in which the game is not like real scientific investigation is that "Mother Nature" is not there to tell you if your hypothesis is right or wrong - the "real" scientist never knows absolutely for sure.

The second activity applies the lessons learned above in the analysis of the phototaxis of blowfly (*Sarcophaga bullata*) larvae (Carolina Biological Supply Company, Burlington, NC) in response to simultaneous challenges with lights of different colors. About an hour before lab, select active larvae which show consistent and strong positive phototaxis toward an incandescent light source. The general experimental protocol the students perform in lab consists of arranging a piece of black construction paper and two adjustable lamps with 60 watt light bulbs on the benchtop as indicated in Figure 2. Secure a color filter (colored cellophane or plastic sheet) over the front of each lamp and adjust the distance between the center of the black paper and each lamp (typically from 5 to 20 cm) so that the light intensity at the larval position will be the same for each color as determined by a light meter. The filters will typically be of two different colors. With both lights turned off, place the larva on the black paper and wait a few seconds for it to right itself and start crawling approximately in a straight line. Rotate and position the paper so that the crawling larva is in the direction indicated in Figure 2 and it is at the correct distances from the two lamps. When the larva is crawling in the desired spot, simultaneously turn on both lamps. Observe the behavior of the larva without further movement of the black paper. When it is clear which direction it is finally moving, simultaneously turn off both lamps. Record the larva's final position as color one, color two, or straight. Repeat this for five trials.

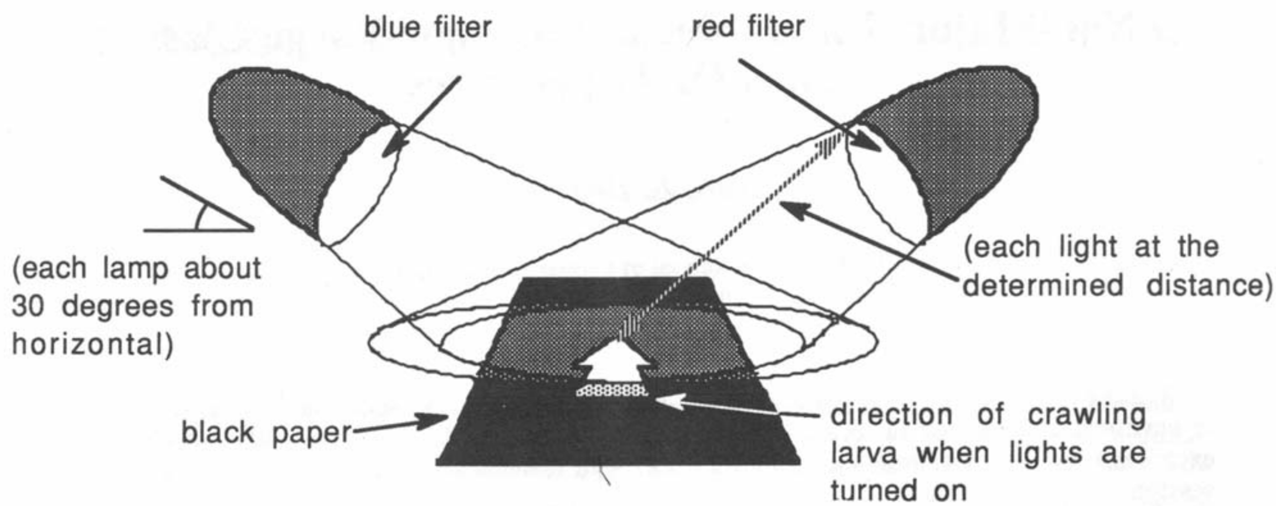

Figure 2. Experimental setup for testing the phototactic response of larvae to different colors of light.

The entire class makes an initial observation using a red and a blue light source, and the findings of all the lab groups are shared. The results are usually very much in favor of the larvae ending up on the "blue" side. Then each lab group forms an hypothesis involving either positive phototaxis toward blue or negative phototaxis away from red, and chooses an experiment from a list of possibilities to test their hypothesis. After sharing the class's results of these further experiments, it should be clear to all the lab groups that a positive phototactic response is being observed. Each lab group then modifies its initial hypothesis and, through further experiments consisting of trials using pairs of various other filter colors of their choosing, tests and further revises its hypothesis until it is consistent with all the data collected by the group.

Pooling the results of the different lab groups at the end of the lab period leads to a more comprehensive hypothesis. The pooled results can be easily summarized by counting the number of preferences each color showed in comparison to others. For example, if pooled class results showed that blue was consistently preferred in choice trials against red, yellow, violet, and no light, but was not preferred in trials against green, then blue would rank four in a "relative preference ranking." In typical sets of trials in which the larvae are challenged with each possible combination of five filters (and no light at all), the "preferred" choices lead to a self-consistent ranking of the colors as to degree of positive phototaxis (most "preferred" color equals a five), with a maximum preference being shown in the green region of the visible spectrum. The students should not be told of such results until the end of lab. Pooling the various class results to put together this "bigger picture" shows the benefit of sharing data and of communicating results to other scientists in the field.

References

Gardner, M. 1977. On playing New Eleusis, the game that simulates the search for truth. Scientific American, 237: 18-25.