Investigative Methods for the Science Teacher

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The basis for this research project was the idea: Why tell or lecture students about an idea or fact when, if given the appropriate information, they would be able to figure it out for themselves? This does not mean that we hand the students a text and tell them to learn about the subject on their own, nor is this "investigative" approach to be used all the time. Because of the different levels of reasoning needed for various topics, one cannot expect a student to deduce the composition of an atom as easily as he can deduce the composition of granite. Some topics have more meaning if they are explained. Others, however, are more meaningful if the student "discovers" them. The topic of this research was to experiment and find ways in which to make certain topics investigative.

One exercise involved the use of facts or explanations that the students had not yet read from their book in conjunction with a picture from the book. The students were given the picture with some additional information and asked to explain what they saw. For example, in one class, lift and drag had been introduced. Then the students were given the following series of pictures: See Figure 1. The students were then told that they were spies and that the enemy country had just developed a new plane which could take off like a Piper Cub, yet reach speeds which their own country's planes could not reach. They were told that the plane was photographed in flight by their own fastest planes going at top speed. The three pictures were taken a few minutes apart just before the enemy's plane sped past them and disappeared. They were to figure out why the plane was able to go so fast and yet was able to use a very short runway.

Figure 1

In the preceding exercise it was obvious that the moving of the wings had something to do with the problem. The students realized the differences in shape and how this factor related to the lift-drag principle, and they could then answer the questions about the plane. Through this exercise the students had to draw together logically the facts concerning lift and drag and apply them to a new situation. If you lecture on the same application, they do not have to do any thinking. This makes class dull so the students do only enough memory work to pass a similar question on a test and forget all about the principle in a short time.

Along with pictures, students can also interpret data if given the chance. For example, the students in this class plotted daily times (horizontal axis) *versus* temperature (vertical axis) from the Des Moines Register weather map. They were asked to explain the various up and downs in the graph for different days. Students know enough about weather from their own observations and by listening to television that they can explain most of the major temperature changes seen on the graph. Figure 2 shows examples of the

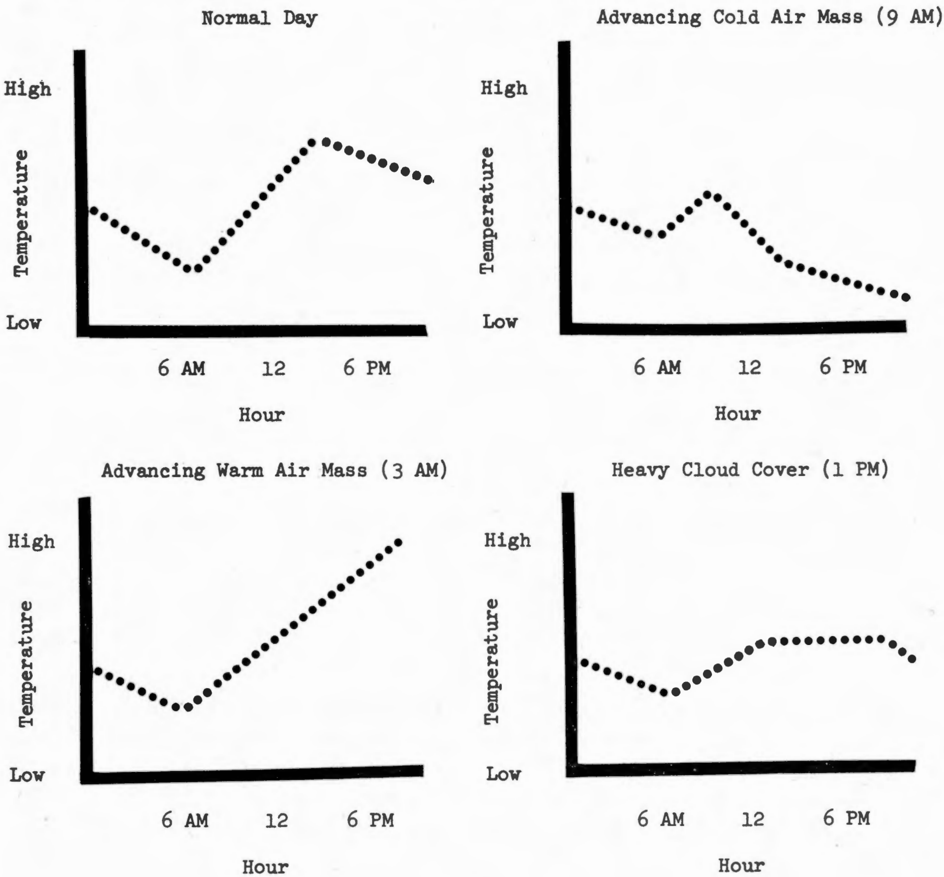

Figure 2

weather graphs. Except for the normal day, all titles were suggested by the students.

If real data is not available, hypothetical data can be supplied for student interpretation. In another class, the following graph was given: See Figure 3.

The students readily noticed that some towns produced more artists and actors than did others. They were then asked to find reasons why this was true. With a little research, they soon found that the towns with higher numbers were slums, while the lower numbers were associated with rich suburbs. Various reasons were given as to why more actors and artists originated in the slums.

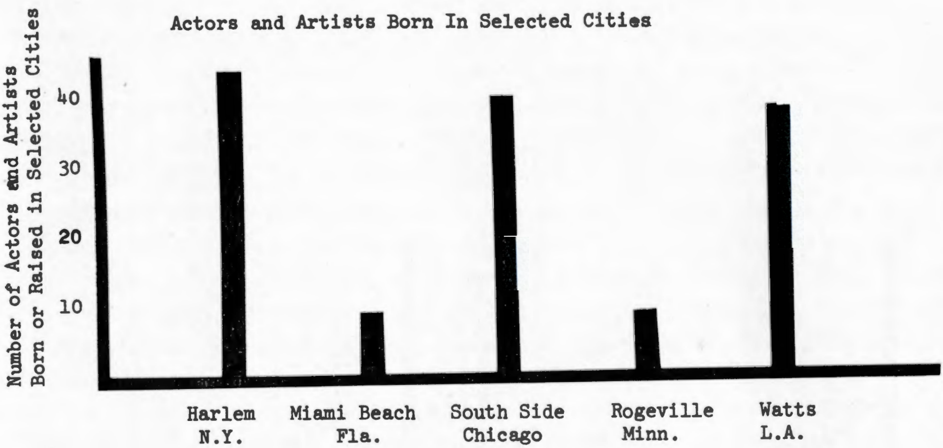

Figure 3

On some topics the students actually went through the original experiments and reasoning of the early scientists. For example, they made simple pinhole cameras with waxed paper backs and could easily see that the image of a candle is inverted. With a little thought they came up with the principle that light travels in straight lines. This experiment caused some problems because students already were conditioned to think that light travels in straight paths and so were not always able to recognize something which they already assumed to be true. In the same manner, they discovered the fact that light can be reflected and that it is reflected at the same angle at which it hits a flat surface. This was done by doing the standard physics experiment using two pins and a mirror, but the students were told only how to set it up. They were allowed to see that the angles of incidence and reflection were the same.

Another exercise used the method of the astronomers. The students were given a picture of a portion of the sky at night (Figure 4) and asked to tell what they saw. It became apparent to the students that stars are not pointed but are round, fuzzy blobs of light; the students also saw that stars are not the same size (brightness) and are not regularly spaced. When these observations were made, the students were then asked to classify the stars. The most obvious way was by size (brightness). After several groupings, the concept of magnitudes was explained in its modern terminology.

Another approach tried was to let the students investigate some industrial problems. The students were told a make a paper plane less than three inches or larger than 12 inches that would fly in a straight path. This required about 1½ class periods for most students. They were then shown how to bend the tail part of the planes and were asked to try to predict how the plane would fly after each bending. After successfully completing this, they were given a biology probe and thin cardboard wings and asked to build darts which were later used in a dart game. In this way it was possible to see who had learned

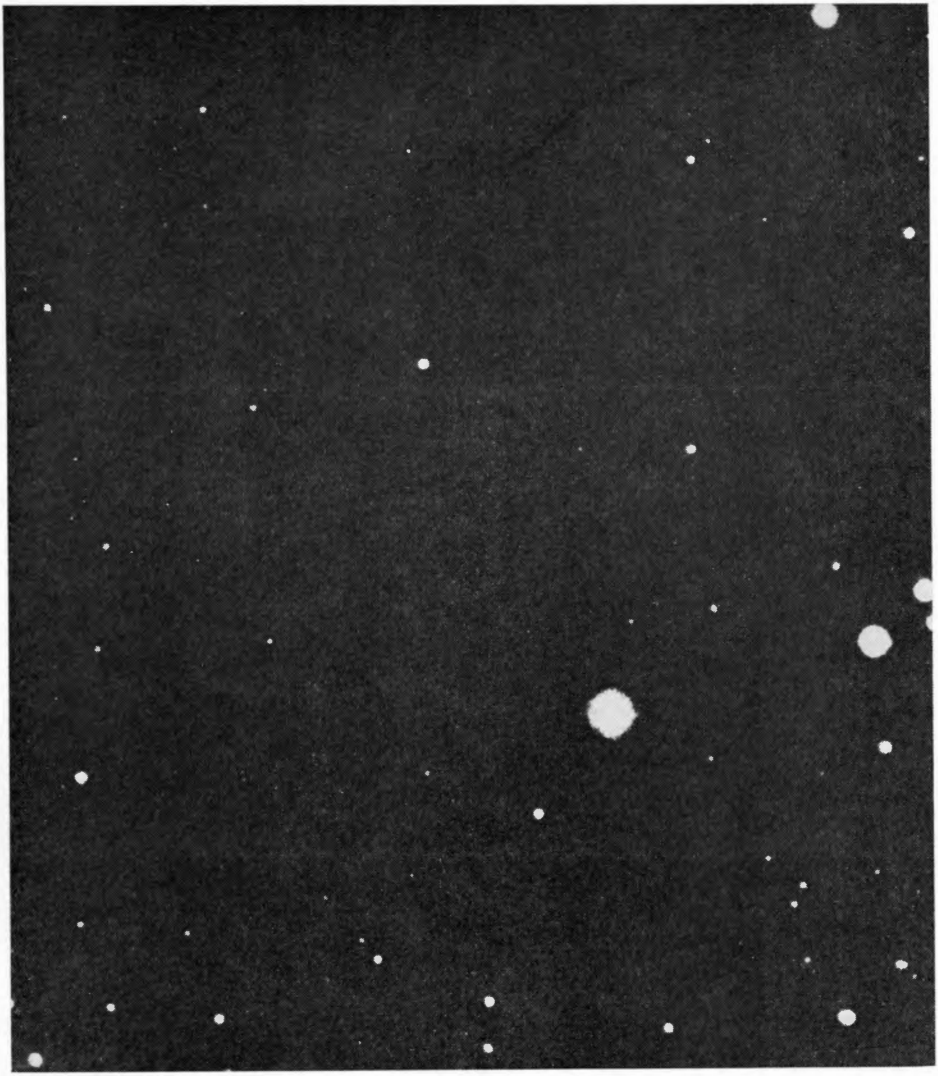

Figure 4

how to apply to the darts the control methods used on the plane. Many students began to use some of these methods after about 1½ class periods. After these exercises, the parts of plane wings and the history of flight were reviewed to enrich the students' feeling of how flight is controlled and the problems it presents. It was noted that a more direct approach would be to have the students try to fly a load in their paper planes instead of building the darts.

Another investigative approach was through steam turbines built in class. Turbines were built from three-inch diameter copper circles with a section of glass tubing inserted through the center for an axle. Supported straight pins were inserted into the glass tube to serve as bearings. The steam source was a flask stoppered with a one-hole stopper that had an eyedropper in the hole to serve as a steam jet. Work and power could be measured by attaching a string to the axle, attaching various weights to the string and measuring the time needed to raise the weight from the bench to the axle. The students were then told that vanes needed to be cut in the copper sheet so the steam had something to push against, and a model was demonstrated. The students were to work on their own to try to see how much horsepower they could develop. After three class periods, several students had been able to improve their turbines from less than .001 hp to .05 hp and greater. All students had proposed ways to improve their turbines which were exactly what industries have had to do to improve theirs.

All of these exercises were devised on the principle of letting a student discover something instead of having the teacher tell him. What the students learned from these exercises was a product of their own thinking. The teacher did not do the thinking and then hand the students the results. The teacher acted only as a guide or reference. The students have learned, not memorized. The student was involved so that interest was high and discipline needed was low. The students brought into use anything that they had previously experienced, and thus what they learned was more relevant. These exercises were used in conjunction with other types of exercises and traditional lecture-demonstration classes. The teacher presented the more difficult concepts and gave certain pre-lab background, reviews and historical enrichment of a topic. In this way, the students learned something and class was more interesting; the students learned to observe, generalize, hypothesize and predict—all basic steps in the scientific method. This approach also helps to work off fat that may have accumulated on students' thinking muscle.

Grading Practices: A Current Bibliography

This article, published by the Commission on Undergraduate Education in the June issue of the Biological Sciences *News*, is now available from CUEBS, 3900 Wisconsin Avenue, N.W., Washington, D.C. 20016. It is a brief bibliography listing 42 items pertaining to grading practices and their reform.