Why Inquiry?

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ALTHOUGH TEACHING SCIENCE by inquiry has become widely recognized as a viable approach, it still remains a lesser alternative to traditional science teaching in many schools. One reason (and there are many) for the mediocre impact of the curricula in some schools is the need for more immediate evidence that science by inquiry is an effective learning experience.

In an attempt to provide this kind of evidence, two groups of students were compared by means of a questionnaire. One group of 77 students had completed nearly one full year of Introductory Physical Science (IPS). This inquiry approach to physical science was offered in the ninth year to students with reading levels of 10+ in grade 8.7. This group was called the discovery group. The second group consisted of two honors chemistry classes from which 30 students were randomly selected to complete the questionnaire. No students in this group had been previously exposed to IPS. Since the chemistry classes were teacher-oriented, this group was classified as the traditional group. The reading level of the group was 11+, slightly superior to the discovery group. The questionnaire was administered after almost one full year of chemistry. Although honors chemistry was characterized as a laboratory course, students spent 25% less time in the laboratory than the IPS group.

The Questionnaire

The questionnaire contained 64 statements, constructed to highlight those learning characteristics that would easily be identified as desirable by both the discovery and the traditional teachers in their classrooms. An attempt was made to balance the questionnaire with both viewpoints, but no measure of internal validity was undertaken.

For each statement, the student was requested to check one of three choices: agree, disagree, or no opinion. Some of the key statements that showed a significant difference in response between the two groups are shown in table 1.

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Tallies were computed for each statement as the percentage of students that agreed, disagreed, or had no opinion (table 1).

In the statistical analysis of the data, a two-tailed test of proportions was performed to determine significant differences of response between the two groups to each statement. The purpose of this method was to determine which of the groups showed significantly greater agreement or disagreement with the statement.

General Observations

One important assumption of this study was that the two groups chosen were truly representative of a traditional and a discovery approach to science. On the basis of the responses to statements 4, 5, 7, 11, and 18, this appears to be a valid assumption.

Students in the traditional group relied on the textbook for specific directions to laboratory experiments. They felt that the experiments were not helpful in answering problems posed in the textbook. Because these students usually knew what results to expect from an experiment, their laboratory experience was one of confirmation of fact rather than discovery.

The responses of the discovery group indicated that students took responsibility for the experimental setups. Experimentation was characterized by a quantitative analysis of results not found in the textbook. Since their laboratory work represented new experiences, not confirmations of previously acquired facts, discovery is a valid classification of this group.

What impact did science by inquiry have on the learning patterns of the discovery group? It appears that these students were able to identify problems, make observations, and draw meaningful conclusions from their laboratory experience. Facts were acquired through experimentation that was success oriented, therefore enjoyable. This strongly parallels a recognized psychological fact that learning occurs best in an atmosphere which is devoid of coercion and is success oriented.

The greater agreement of the discovery group than the traditional group on statements 9, 10, 11, and 45 clearly indicates that the inquiry approach provides the student with the opportunity to experience the process of science and to learn through this experience. Not only was the discovery group better able to draw conclusions, but statement 10 showed that 83% actually learned from their experience. The discovery group was not embedded in the traditional rhetoric of conclusions; these students learned to formulate and test hypotheses, gather data, and interpret results. Science by inquiry proved to be a tool for learning as well as a learning experience in itself.

Experiencing the process of science was also enjoyable for the discovery group, as evidenced by a 60% agreement with statement 19. It is becoming increasingly evident that if learning is to be more retentive and transferable to new situations, the affective domain must be recognized as an essential component in learning. Because the discovery group was provided

Table 1. Comparison of the two groups.

Statements	Discovery (n=77) Agree	Discovery (n=77) Disagree	Discovery (n=77) No opinion	Traditional (n=30) Agree	Traditional (n=30) Disagree	Traditional (n=30) No opinion	Significant Differences: Discovery Agree	Significant Differences: Discovery Disagree	Significant Differences: Traditional Agree	Significant Differences: Traditional Disagree
4. Too much time setting up equipment	51	47	2	20	70	10	0.01	-	-	0.01
5. Text gave enough information to carry out experiment	43	44	13	80	20	0	-	0.01	0.01	-
7. Too much math in course	47	43	10	7	87	6	0.01	-	-	0.01
9. First science course in which I could make observations and draw conclusions	83	13	4	13	77	10	0.01	-	-	0.01
10. Discovered facts in laboratory which were not explained in book	83	9	8	50	43	7	0.01	-	-	0.01
11. Many questions in book could only be answered by experiment	77	14	9	40	53	7	0.01	-	-	0.01
18. Usually expect the results of experiment	41	49	10	70	26	4	-	0.01	0.01	-
19. Enjoyed the experiments more as term progressed	60	27	13	37	47	16	0.05	-	-	0.05
32. More than two students working together is too confusing	60	31	9	37	60	3	0.01	-	-	0.01
40. Could refer to my notebook at later date and reconstruct experiments	63	33	4	63	33	4	-	-	-	-
45. Easier to draw conclusions from experiments at end of term	66	26	8	43	37	20	0.05	-	-	-
47. Teacher should perform more demonstrations	45	40	15	70	16	14	-	0.05	0.05	-
57. It is important to study for tests	52	34	14	83	4	13	-	0.01	0.01	-
58. If I do not do well in lab, I still get the same grade on tests	41	44	15	60	16	24	-	0.01	0.05	-
64. Never really understood science until this course	21	56	23	0	87	13	0.01	-	-	0.01

Responses to Statements in Percentage of Students

with options in experimental design, observations, and data collection, the students enjoyed the success of their self-initiated learning. This is not meant to imply that a pleasant experience represents learning but rather that learning is more retentive if the experience is enjoyable.

A characteristic of the traditional approach is the use of the laboratory as a confirmation of fact. Statement 18 showed that 70% of the traditional group knew the results of the experiments without performing them. Although some students may have benefited from the reinforcement of concepts provided by laboratory work, statement 58 showed that 60% of the traditional group learned very little from their laboratory experience. Since 70% of the traditional group agreed with statement 47, this laboratory setting may have precipitated a greater reliance on the teacher in problem-solving situations, thus stifling creativity.

It should be pointed out that even in the discovery group, 41% of the students had prior knowledge of experimental results (statement 18). However their responses to statement 45 suggest that they learned to formulate hypotheses. Prior knowledge may very well have been interpreted as the confirmation of well-formulated hypotheses by the discovery group.

Statement 57 represents another interesting point of departure between the two groups. A significantly greater percentage of traditional students than discovery students thought it was important to study for tests. There are two possible interpretations of this response. The result may simply reflect differences in test content, emphasis, or construction between the two groups. More importantly, the greater disagreement with this statement by the discovery group may indicate that retention of learning experiences through the laboratory work carried over into the examination. Students may have felt confident in their understanding of concepts well in advance of the examination.

It is interesting to note that a large percentage of students in both groups could refer back to their notebooks to reconstruct experiments from their data and observations. Although few directions for performing experiments were supplied to the discovery group,

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ISP 2 plate. Incubate the inoculated plate for 5–7 days. Crabtree and Hinsdill (1974) recommend antibiotic assay soft agar in place of ISP 2 medium. Its ingredients are 5.0 g tryptone; 5.0 g peptone; 3.0 g yeast extract; 1.0 g beef extract; 2.0 g glucose; 7.0 g agar; and 1 liter water. This substrate is not only richer but allows more rapid diffusion of antibiotics if an organism is producing them. Invert and incubate the plate at room temperature in the dark for 5–7 days. After that, streak representative gram-positive and gram-negative test bacteria at right angles to the actinomycete streak. Not all actinomycetes will produce antibiotics that inhibit bacterial growth, but some do. Again, poor or no growth of the test bacteria indicates

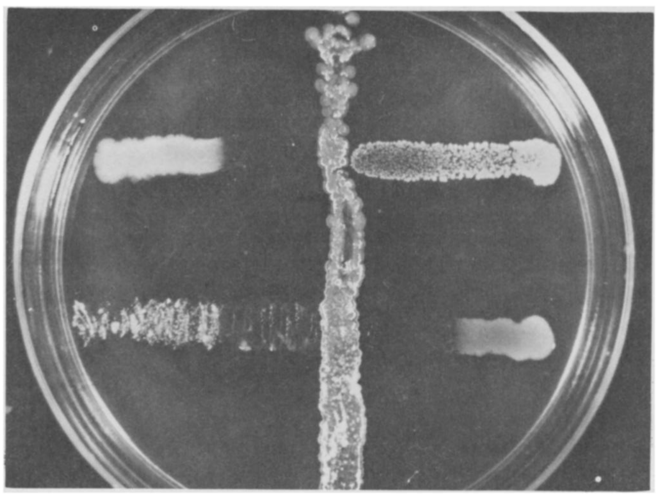

Fig. 3. Test for antibiotic production. Upper right, *Sarcina lutea* (resistant); lower right, *Escherichia coli* (susceptible); upper left, *Proteus vulgaris* (susceptible); lower left, *Staphylococcus aureus* (susceptible).

that they are susceptible to some diffusible substances produced by the actinomycetes (fig. 3). If kept refrigerated, the spore suspension often stays viable for 15–18 months and can be used in subsequent experiments.

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these students still felt as confident in their ability to plan experiments, make observations, and draw conclusions as the traditional group which was provided with directions. The discovery group learned without teacher-initiated protocols.

In analyzing the responses of the two groups, the following facts are quite clear: (i) the traditional group showed a reliance on the teacher for learning; and (ii) knowledge alone seemed to be the factor in determining the degree of involvement and achievement. By their responses, the students in the traditional group indicated that they understood science to be a body of immutable conclusions about science. In contrast, the discovery group understood science to be the process of discovery. Statement 64 shows that 21% of this group came to this understanding. None of the students in the traditional group agreed with the statement.

Active Student Involvement

The results of this study clearly delineate two approaches to science education. With one approach, the student will discover facts on his own; he will learn to draw conclusions from careful observations; and he will achieve an understanding of science while enjoying his learning experience. This approach places the student in a learning situation that makes the process of science a real experience while enhancing critical thinking.

The second approach presents knowledge as true and permanent. Students rely on the teacher for the information and regard factual knowledge as the sole determiner of their achievement. Since it is clearly teacher-oriented, situations which require critical thinking are relegated to the teacher, not the student. In essence the student is the passive observer.

If the goal of science education is the active involvement of the student in the process of science, the choice is clear.

About the Cover

The sketch of the Rhesus macaque on the cover of this issue was done by Douglas L. Cramer while serving as staff artist at the Oregon Regional Primate Research Center. Cramer is currently assistant professor in anthropology at Rutgers University and lecturer in anatomy at New York University Medical School. A four-and-a-half hour tour of the Primate Research Center has been scheduled for the NABT convention in Portland later this month. The Center conducts frontier studies in biomedical research through the use of primates.