A Successful Inquiry Methodology

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INQUIRY HAS MANY ASPECTS. It includes cognitive skills (formulation of problems, formulation of hypothesis, etc.), associated attitudes (curiosity, openness, etc.), and the outcomes of inquiry (knowledge of concepts and principles). The basic definition of inquiry we have utilized is "a set of activities directed towards solving an open number of related problems in which the student has as his principal focus a productive enterprise leading to increased understanding and application" (Bingman 1969).

Many new high-school biology textbooks and programs claim to be "inquiry-oriented." But textbooks, even when used with a variety of supplementary materials, can help students acquire only limited kinds and numbers of inquiry skills and attitudes. A variety of cognitive factors and attitudinal qualities has been identified as essential to inquiry (Bingman 1969), including formulating problems and hypotheses, designing and executing studies, interpreting data or findings, synthesizing new knowledge, curiosity, openness, objectivity, precision, confidence, satisfaction, and responsibility. These skills and attitudes are useful for studying biology and also many other areas of interest or need. They are useful for the biology student who is interested in further study of science and also for the many students who will have their only formal exposure to science through biology. An inquiry-oriented approach to high-school biology should develop these types of skills and attitudes. Proper development depends on more than the text or supplementary materials. It depends heavily on the teaching process used in the classroom to elicit inquiry behaviors, to create student interest, and to motivate students to participate. There is, then, a need for a teaching methodology providing a way to use the available inquiry-oriented curriculum materials.

The Inquiry Role Approach

For six years the Mid-continent Regional Educational Laboratory has worked to provide such an approach. The result is the Inquiry Role Approach (IRA) program (Bingman et al. 1974), a teaching methodology for secondary-school biology. The program includes teacher-training materials, teacher instructions for class use, and student materials. These materials are designed to complement, not supplement or substitute for, the biology textbook. Program goals include learning biology content—factual information, concepts, and principles of biology. Emphasis is also on the development of cognitive inquiry skills, social interaction skills, and the attitudes consistent with cognitive inquiry. The IRA methodology is based on the premise that biology content understanding, inquiry skills, social skills, and attitudes are interdependent and can be achieved best in a program that integrates them. The early development and rationale for this "four-pronged"

The authors are members of the staff of Mid-continent Regional Educational Laboratory, 104 E. Independence Ave., Kansas City, Mo. 64106. Pictured are Lowell A. Seymour (*right, above*), work unit coordinator for the Inquiry Role Approach program; Lawrence F. Padberg (*right, below*), a program development specialist; and Paul G. Koutnik (*left*), coordinator of the Inquiry Skill Research Development and Adaptation program. For a biographic note (with photo) of Richard M. **Bingman**, who is a McREL program development specialist, see *ABT* 34(6): 346. **Seymour** is a 1961 graduate, in biology, of Hope College; he obtained his M.A. from Montclair State College and his Ed.D. from Temple University, where he taught science education. A former teacher in New Jersey public schools, he has also served as a research associate for Philadelphia schools and is the author of research papers for the National Association for Research in Science Teaching (NARST) and the Association for Children with Learning Disabilities. **Padberg**, a 1967 graduate, in biology, of Rockhurst College, has taught high-school biology at Roeland Park, Kan. He was awarded an M.A. in physiology from the University of Missouri last May. He, too, has done research for NARST. **Koutnik** obtained his B.S. and M.S. degrees, in zoology and biology-teaching, from the University of Illinois in 1959 and 1961. He taught biology at Joliet, Ill. until 1966, and he taught science education and received his Ed.D. degree at Indiana University in 1968. He has presented research papers through NARST, the Association for the Education of Teachers in Science, the National Science Teachers Association, and the American Educational Research Association.

approach have been reported previously (Andersen et al. 1971; Andersen and Koutnik 1972; Bingman 1970; Bingman and Koutnik 1970; Bingman et al. 1972; Bingman and Stothart 1972; Koutnik 1970; Lee and Steiner 1970).

Once an inquiry-oriented methodology has been developed, the biology teacher must ask: Can students develop inquiry skills? How does students' development in the inquiry-oriented class compare to their development in other classes? Do students prefer classroom settings when inquiry is emphasized and developed? Can teachers learn and execute the new methodology adequately to attain the intended outcomes? The recently completed field test of the IRA program was designed to answer these questions (Seymour et al. 1973). This paper focuses on a description of the field test and a report of the results.

During the 1972-73 academic year 15 teachers, with about 1,300 students, used the IRA materials. All classes were first-year biology classes. About 80% of the students were in the 10th grade. The biology text used was the BSCS Yellow Version, *Biological Science: An Inquiry into Life* (Biological Sciences Curriculum Study 1968).

A variety of data from pretests, interim tests, and posttests was collected for evaluating the program. Student feedback regarding teacher performance, class activities, and student preferences for IRA practices also were utilized. Teachers supplied feedback to us in log reports completed after each activity.

Results of Appraisals

Can students develop inquiry skills? Randomly assigned samples of the IRA students were pretested and posttested with the Explorations in Biology (EIB)—Topic 1 instrument (Koos 1969–72), designed to measure 14 cognitive inquiry skills in formulation of problem and hypothesis, experimental design, interpretation of data, and applications and synthesis of knowledge. (Data for problem-formulation skills were not analyzed, due to the low reliability of this part-score.) Inquiry Role Approach students demonstrated significant pre-to-post gains on the part scores for hypothesis formulation, experimental design, interpretation of data, and application and synthesis of knowledge ($P < .001$ for all) and on the total Explorations in Biology—Topic 1 score ($P < .001$).

The Biology Student Behavior Inventory (BSBI) (Steiner 1970) was administered pre and post to evaluate specific attitudes considered related to inquiry: curiosity, openness, satisfaction, and responsibility. Students demonstrated significant pre-to-post gains on the part scores for curiosity ($P < .006$), openness ($P < .001$), and responsibility ($P < .001$), and on the total Biology Student Behavior Inventory score ($P < .002$).

How does development in the inquiry-oriented class compare with development in other biology classes? Eight teachers using the BSCS Yellow Version, with approximately 600 students, acted as a nonequivalent comparison group. (It was not possible to randomly assign teachers and students to experimental and control groups for the field test. Pretesting with the Differential Aptitude Tests [Bennett et al. 1959] for verbal reasoning and numerical ability showed that the students used as a comparison group scored significantly higher [$P < .01$] than students placed in the experimental group. The experimental group attained mean scores placing them at the 60th percentile for verbal reasoning and at the 50th percentile for numerical ability.)

The IRA students scored significantly higher on the Explorations in Biology and the Biology Student Behavior Inventory posttest: see fig. 1 and 2. (The comparison of Explorations in Biology part scores—problem and hypothesis formulation, design, data interpretation, synthesis of knowledge—could not be treated separately, due to the way non-IRA raw

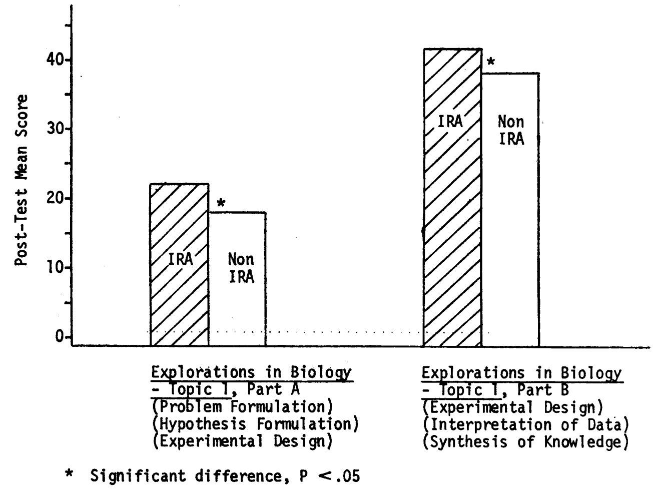

Fig. 1. Comparison of Exploration in Biology posttest mean scores for IRA and non-IRA students.

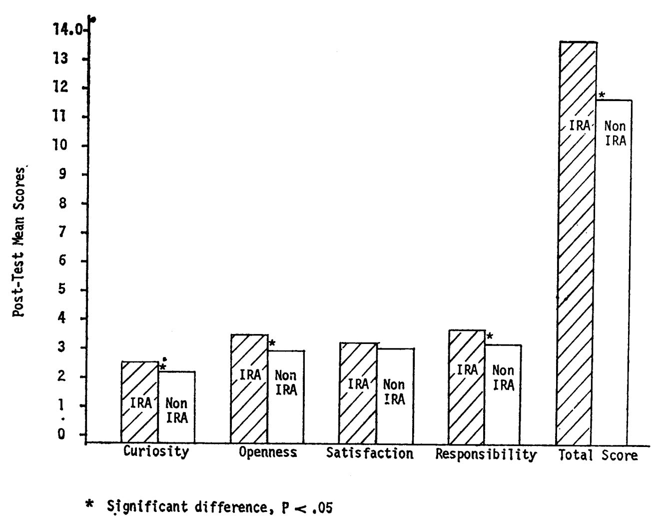

Fig. 2. Comparison of Biology Student Behavior Inventory posttest mean scores for IRA and non-IRA students.

data were identified.) Students where the IRA inquiry methodology was used scored significantly higher on instruments designed to measure cognitive inquiry skills and attitudes associated with inquiry than did students where this methodology was not used.

Students in non-IRA classes scored significantly higher in biology content comprehension, as measured by the Comprehensive Final Exam (Biological Sciences Curriculum Study 1965). The difference in total mean scores of approximately 2 points is probably due to several factors. Teachers using the IRA materials indicated that they treated less content during 1972–73 than during previous school years. This appears to be partly due to the added demands of the inclusion of inquiry skills, social skills, and attitudinal objectives, particularly for those teachers using the IRA materials for the first time. Also, disparity in verbal and numerical abilities of the IRA and non-IRA students may account for some of the differences in content scores. This result is not consistent with testing in previous years of IRA development, in which IRA students surpassed non-IRA students in content comprehension (Bingman 1970: 29–30).

The IRA materials have been revised in light of field-test findings. Revisions include increased clarity of objectives, increased biology content coverage, and simplification of directions and student materials. These changes have made the program materials more easily usable.

Do students prefer classroom settings where inquiry is emphasized? The Views and Preferences (Form C) (Seymour and Bingman 1973) was given to students. This instrument is designed to allow students to state whether certain practices considered characteristic of the IRA occurred in their classes. Students also indicate whether or not they prefer these practices. Three categories are identified: social behaviors, cognitive behaviors, and class procedures. Possible responses to items are these: strongly disagree, disagree, undecided, agree, and strongly agree. The instrument was administered midway through the year (interim) and at the end of the year (post).

On average, more than 90% of students (90.6% interim, 93% post) preferred (answered agree or strongly agree) the social behaviors characteristic of the IRA inquiry classroom. More than 50% (50.5% interim, 50.1% post) preferred the cognitive behaviors. Classroom procedures were preferred by 85.6% (both interim and post). The percentage showing agreement for all preference items combined was about 75% (74.8% interim, 75.6% post).

Training of Teachers

Can teachers learn and execute the new methodology adequately to attain the intended development? To evaluate how well teachers implemented the program, a method of categorizing implementation was devised. Classification in one of the three categories was based on criteria in four areas: (i) percentage of IRA activities performed; (ii) teacher-reported percentage of students meeting objectives for those activities that were performed; (iii) students' views of whether desired practices were being performed (data taken from "views" items of Views and Preferences—Form C); and (iv) students' views of teacher characteristics and classroom procedures as measured by the Class Activities Questionnaire (Steele et al. 1971).

Five teachers achieved very adequate implementation. Nine achieved adequate implementation. Only one did not adequately implement the program (this teacher chose to emphasize, strongly, social and attitudinal development and, therefore, fell below the criterion for percentage of activities performed. His students demonstrated substantial attitudinal gains on the Biology Student Behavior Inventory).

A variety of training or orientation procedures was used to prepare the 15 teachers for implementing the IRA program. Six teachers were trained in a two-week summer workshop directed by the IRA developers, two worked independently at their respective schools, and the others trained at least one other teacher in their school. During the school year, therefore, they (and the teacher or teachers trained by each) benefited from frequent interaction with another IRA teacher. The four "teacher-trainers" trained seven teachers. Two additional teachers had previous experience with the IRA program and received no additional preparation.

Our experience with these teachers indicates that with training to orient the teacher to the IRA methodology, successful implementation can be expected, and that "teacher-trainers" can train successfully other teachers. Teacher materials have been redesigned to be more self-instructional, so the program can be implemented successfully with only minimal orientation.

Conclusions

Experience with the IRA program indicates curriculum materials designed to be inquiry-oriented should not be considered adequate for developing inquiry skills in students. A complementary teaching methodology (such as the IRA) is necessary, so teachers learn how to elicit inquiry behaviors from students.

The Inquiry Role Approach program has been shown to be a successful inquiry teaching methodology for use with modern inquiry-oriented biology textbooks. Students have shown significantly higher inquiry skill and attitude development in classes using the IRA program, compared with similar non-IRA classes. Students also have indicated a preference for the social behaviors, cognitive behaviors, and classroom procedures characteristic of the IRA inquiry classroom. Successful first use of the program has been demonstrated by 11 of 12 teachers.

The revised IRA materials have been published by Silver Burdett Publishing Co., Morristown, N.J.

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functions of these entities. That conventions can change is illustrated by reforms carried out at Evergreen State College, Governor's State University, and Hampshire College. These are new schools, which started off with different conventions. Whether or not the existing educational establishment can change its conventions is a moot question.

It is not likely that changing the traditions of established institutions will be easy. However, the one sure way to avoid the world of Big Brother is to have a citizenry of autonomous thinkers. If biology departments and schools have the slightest commitment to the future, it is imperative that they change some of their conventions. Not to do so is, in effect, a denial of the goal of developing intellectual autonomy.

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NSF Chautauqua-Type Short Courses

NSF Chautauqua-type short courses open to college biology teachers are being offered in twelve field centers. A few of the course titles are Human Heredity and Societal Problems; Behavior–Genetic Analysis; Human Sexuality; Ethical Issues and the Life Sciences; Ecological Strategies for Human Survival; Water Pollution; Biosociology; and Man and His Food Supply. For information about the program write to Project Director, Chautauqua-Type Short Course Program, AAAS, 1776 Massachusetts Ave., Washington, D.C. 20036.