Intellectual Development, IQ, Achievement, and Teaching Methodology

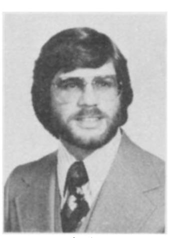
Edmund A. Marek
John W. Renner

FOUNDATIONS, GOVERNMENT, and well-known individuals have become interested in and exerted an influence upon the curriculum of the schools in the last two decades. Those influences introduced to United States education many new factors that had previously been ignored, including the involvement of the professional scientist in curriculum development. The professional's intervention was to ensure that the accuracy of the discipline's structure would be built into new and revised science curricula.

In examining those scientist-advised, secondary-school curricula, one is struck by their tendency to use the abstract models of the disciplines. That tendency suggests that perhaps the intellectual development of the learners did not receive much consideration. Our thesis is that the more abstract the concept to be learned, the greater the degree of intellectual development required. Research data suggest that many students could not learn from such curricula because they had not reached the required level of intellectual development (Lawson and Renner 1975; Piaget, Inhelder and Szemniska 1964). Kohlberg and Gilligan (1975) succinctly described this curricula-student intellect mismatch by saying, "Clearly the new curricula assumed formal operational thought rather than attempting to develop it."

How important is considering the state of intellectual development in curriculum development or in teaching? A theory of intellectual development must be subscribed to before that question can be addressed. Of all the current theories of intellectual development, the one that has probably generated the most activity, excitement, controversy, and research in the last ten years is that attributed to the Swiss biologist-psychologist-epistemologist Jean Piaget. From the research of Piaget and his interpreters, greater understanding of cognitive development and logical thinking has resulted. Some basic questions are, however, left unanswered. Can intellectual development, IQ, and achievement be enhanced by classroom use of the inquiry teaching methodology? The research reported here provides evidence to enable the question posed in this paragraph to be answered.

The attributes of IQ and achievement have concerned educators for some time, but intellectual development as a unique, measurable quantity that provides specific information about students is relatively new on the educational scene. Many persons assume that it is a measure of IQ or is closely related to IQ. Whimbey (1974) says: "IQ tests do not measure innate intellectual capacity, but rather a group of learned skills that can be taught in the classroom or in the home." Specifically, according to Whimbey, they measure the learned ability to form relations with verbal and symbolic concepts. DeVries (1973)



Edmund A. Marek is assistant professor of biology at Southwest Texas State University, San Marcos 78666. Prior to teaching at this institution, Marek was adjunct assistant professor at Oklahoma University (Norman), as well as secondary science coordinator for the Norman Public School System. He received his Ph.D. degree in science education from the University of Oklahoma in 1977. He has taught biology at both the high school and middle school levels. Marek was nominated as an NABT Outstanding Biology Teacher in 1974, 1975, and 1976, and was the recipient of the Outstanding Teacher Award from the Norman Public School System in 1975 and 1977. He holds memberships in the National Association for Research in Science Teaching, the NEA, and the Science Teachers Association of Texas. John W. Renner is professor of science education at the University of Oklahoma (Norman), a position he has held since 1962. He received his Ph.D. degree in science and mathematics education from the University of Iowa in 1955. Renner directed a Cognitive Analysis Project in 1976 under the auspices of the National Science Foundation, and his research interests center on intellectual development and science curriculum and teaching methodology. He has published extensively in a number of journals, including *ABT*. Renner holds memberships in the National Association for Research in Science Teaching, the NEA, the National Science Teachers Association, and Phi Delta Kappa.

concluded that psychometric mental age, determined from the Stanford-Binet Intelligence Scale, is not a reliable predictor of Piagetian stage development except in the general sense that brighter students become concrete operational earlier. A more recent study (Renner, J., Prickett, and Renner, M. 1977), however, reports that a correlation of 0.44 was found between performance on the *Short Form Test of Academic Aptitude* and interviews with tasks designed by Inhelder and Piaget (1958). The latter research places the "general sense" relationship between IQ and intellectual development of DeVries into the realm of a positive, measurable relationship.

IQ has been used for many years to predict student success. Because a positive relationship has been established between IQ and intellectual development, a measure of intellectual development should be useful in discussing student achievement. Two studies seem to confirm that inference.

Sayre and Ball (1975), using several tasks designed to measure formal thought, studied the relationship between the performance of junior and senior high school students on those tasks and student grades in science. They concluded that junior and senior high school students operating at the formal level received significantly higher (.0l) science grades than those operating below that level. Lawson and Renner (1975) found that concrete operational students had developed no understandings of formal concepts that they had studied and not until students had entered the formal thought period did they begin to demonstrate understandings of formal concepts. Formal operational students did demonstrate understandings of formal concepts.

To study the three variables being discussed—IQ, intellectual development, and student achievement—a classroom setting was necessary. We elected to study in our tenth grade biology classes the relationships between those variables and a teaching methodology we labeled "inquiry." Specifically, we asked this question: *How are intellectual development, IQ, and achievement affected by inquiry teaching methods?*

In our inquiry teaching method we provided students with materials and directions for interacting with them before students had verbally experienced the concept(s) the materials could lead them to learn. Teacher intervention occurred in supplying materials and providing language for the concepts *after* the students had experienced them.

Three prior studies done at the Science Education Center, University of Oklahoma, led us to hypothesize positive relationships between inquiry teaching methods and the three variables of IQ, intellectual development, and student achievement. Stafford and Renner (1971) showed that more first grade children who were taught with an inquiry science program—Science Curriculum Improvement Study (SCIS)—entered into the concrete operational state, as measured by the Piagetian conservation tasks, in the same time period than did students not experiencing the first-grade SCIS program. The latter group studied a conventional textbook science program. In addition to this study with elementary school subjects, Friot (1976) showed that eighth and ninth-grade learners, who were involved in an inquiry-type science program demonstrated signigicant gains in their ability to think logically. The comparisons were with learners who were enrolled in a traditional lecture-demonstration type science course. Friot also found no significance between IQ and attainment of formal operational thought by junior high school students. McKinnon and Renner (1971) found that the increase in formal operational thought patterns of college freshmen enrolled in a course that used inquiry techniques was significantly greater than among those freshmen not experiencing that teaching methodology.

Using a table of random digits (Minium 1970) a sample of 100 subjects was selected from students enrolled in a first-year biology course at a midwestern high school. The experimental group was taught using the inquiry method during the entire 1976-77 school year. Ninety-two of the subjects completed the study.

The IRA Program

The treatment was implemented using the Inquiry Role Approach (IRA) program designed and evaluated by the Mid-Continent Regional Educational Laboratories (1974). IRA was designed to develop inquiry and social skills, understanding of biology content, and attitudinal qualities. Specific goals included: (1) inquiry skills—formulating problems and hypotheses, using science literature, designing experiments, interpreting data, and synthesizing new knowledge; (2) social skills—coordination and communication with classmates, social interaction, and role performance; (3) content—knowledge of biology principles and concepts in ecology, bioenergetics, cell biology, and scientific research methodology; (4) attitudinal qualities—curiosity, openness, satisfaction, and responsibility.

Approximately one-third of the class time was devoted to working in three- or four-member groups. The class work (IRA activities) is explained later. To facilitate this small-group performance, each team member had unique responsibilities in each group. Those responsibilities are described by structured roles (Mid-Continent Regional Educational Laboratories 1974) the students fulfilled. The descriptions of the roles follow:

Discussion Coordinator: This person has the responsibility to lead the team in discussions that will answer content questions (for example, answering laboratory report questions). In laboratory investigations the Discussion Coordinator is responsible for leading the team in writing the title, determining the purpose, and answering the report questions of the experiment.

Technical Advisor: This team member has the responsibility for leading the team in the performance of the experiments by delegating procedural steps (for example, getting materials, setting up apparatus, and cleaning up).

Data Organizer: The student assuming this role has the responsibility of leading the team members in gathering data and preparing the necessary charts, graphs, tables, and drawings. The Data Organizer presents the team's data to the entire class.

Process Advisor: This team member maintains a daily log of individual performance on all activities, team performance of working together, and the ways that any problems were solved.

The Process Advisor leads the group in the team's evaluation of each member in the team. Initially the roles are very structured and mechanical, but as the team becomes familiar with the IRA activities and gains experience the roles become more flexible and overlapping.

Before the group work begins, students read the assignment and prepare those materials for the team directed by their roles. During the course of the year approximately *one-third* of all class time is devoted to individual preparation. Students spent the remaining one-third of the time participating in class discussions of the team work.

IRA Activities

The IRA program consists of three types of classroom activities:

1. *Laboratory Investigations:* The manual that guided the teams in performing experiments is called *Laboratory Investigations in Biology* (Benson and Green 1974). Twenty-six of the sixty-four investigations included were completed as part of the IRA program.

2. *Inquiry Guides:* An inquiry guide (Mid-Continent Educational Laboratories 1974) is a paper-and-pencil problem-solving activity in which the students are given a series of biological statements; for example, "Water and energy are the principal limiting factors to the life of an ecosystem." Their task is to determine if the statement is acceptable or unacceptable and to support their positions with evidence from text and laboratory references. After the inquiry guide was completed individually, team discussions took place. Ten inquiry guides were completed during the research.

3. *Laboratory Explorations in Biology (LEIB):* The LEIBs (Mid-Continent Educational Laboratories 1974) differ greatly from traditional laboratory experiments. During the LEIB each team chooses its own study problem that is developed from concepts introduced in the preceding inquiry guides and laboratory investigations. The teams then formulate a hypothesis for the problem and design experiments to support or disprove that hypothesis. In addition, the teams do research on related literature, gather and interpret data from the experiments, and finally apply the knowledge to related concepts. The last step of the LEIB is a synthesis. In other words, the data and conclusions of the research are applied to other biological situations; generalizing from factors that affect yeast populations to the human population is an example of such a synthesis. Teams usually spend the entire class period for a full month pursuing a LEIB, after which they report to the class.

LEIB, the culminating activity of the content areas, is preceded by completing related laboratory investigations and inquiry guides. This sequence of activities constitutes a cycle—laboratory investigations, inquiry guides, and the LEIB. Three of those cycles were completed during the experiment. These cycles encompassed ecology, bioenergetics, plus a sampling of many other areas selected by the teams for the third cycle. Included in those areas were topics from microbiology, nutrition, and environmental health.

Design of Study

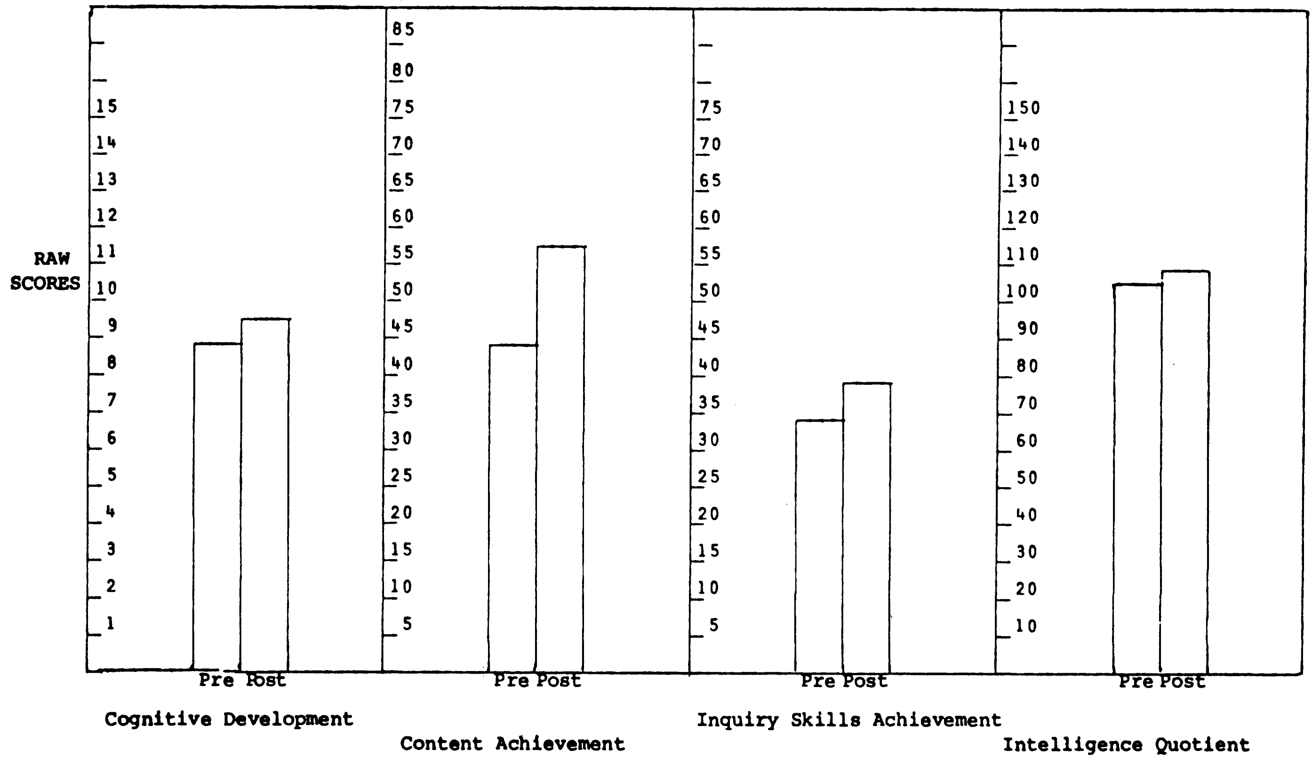
A pretest-posttest design of four parameters (cognitive development, content achievement, inquiry skills achievement, and IQ) was employed to analyze the affect of the inquiry treatment. The instruments used to measure these variables are listed below. Two of the variables, content achievement and inquiry skills achievement, were compared to a control group.

The control group used in this study was part of the IRA field test (Mid-Continent Educational Laboratories 1972) during the 1972-73 school year. Four hundred and sixty-five tenth grade subjects from suburban midwest and west coast high schools constituted the control group. This group was taught by teachers with neither IRA materials nor IRA training. A traditional lecture-laboratory-demonstration course was taught from *Biological Science—An Inquiry into Life* (Biological Sciences Curriculum Study 1968).

Different teachers and teacher attitude are two variables necessary to control or eliminate in the experimental treatment. The teacher variable refers to a situation where the experimental method is taught by different teachers whereas the teacher attitude variable pertains to how that person would approach the teaching act. For example, a traditionally oriented teacher could negatively affect the inquiry teaching method and an inquiry-oriented teacher could negatively affect the traditional teaching method. The researchers believed that a teacher's attitude, education, and personal biases would affect the experimental treatment and subsequently the data. To eliminate the teacher variable and teacher attitude variable one teacher, Marek, taught the experimental group during the 1976-77 academic year. Marek had experienced and conducted IRA training programs and had taught the program for four years.

Because the IRA field-test report of 1972-73 provided

FIGURE 1. PRETESTS AND POSTTESTS MEAN SCORES OF COGNITIVE DEVELOPMENT, CONTENT ACHIEVEMENT, INQUIRY SKILLS ACHIEVEMENT, AND INTELLIGENCE QUOTIENT



control-group data, the control-experimental group design was employed when testing the content achievement and inquiry-skills achievement variables. The variables of teacher and teacher attitude were minimized in the control group because the teachers of the control and test group of the 1972-73 IRA field test were matched in terms of textbook used, experience in teaching, and general teaching approach. These control group data, therefore, had validity with respect to comparing that group's content achievement and inquiry skills achievement to those achievements of the experimental group. That validity is due to the fact that both studies exercised control over the teacher variable, the methods under examination, and the instructional materials used.

Content achievement of the control group was measured by the *Comprehensive Final Examination,* an instrument developed by the Biological Sciences Curriculum Study (1965). BSCS (1971) also produced the Resource Book of Test Items for *Biological Science—An Inquiry into Life*. This book and the IRA program are the sources of the questions used to measure content achievement of the experimental group in the present research. That achievement was measured by the "Biology Content Examination," a teacher-assembled and teacher-made multiple-choice test. Thus the control and experimental groups' content instruments have the BSCS as a common source of test questions.

Inquiry skills achievement of the control group and the experimental group was measured with the "Explorations in Biology" (EIB) test. The EIB was developed and evaluated by Mid-Continent Regional Educational Laboratories (1974) and assesses inquiry skills attainment.

Inhelder and Piaget (1958 and 1964) developed numerous tasks for determining cognitive development. From these tasks four were selected to measure cognitive development in the experimental group only. Included were Conservation of Volume, Combinations of Colorless Liquid Chemicals, Separation of Variables, and Equilibrium in the Balance (Renner, *et al.* 1976).

Intelligence quotient, also determined in the experimental group only, was measured with the *Short Form Test of Academic Aptitude Level Five* (Sullivan, Clark, and Tiegs 1970).

Results

The data produced from administering the four Piagetian tasks, the content examinations, the EIB, and the IQ test (SFTAA) were examined in two phases. The first phase in an analysis of variance in pre- and posttest scores of the experimental group in cognitive development, content achievement, inquiry skills achievement, and IQ; and the second phase is a comparison of the control group to the experimental group in content achievement and inquiry skills achievement.

In the first phase of data analysis, cognitive development, content achievement, inquiry skills achievement, and IQ indices of the experimental group were tested for significance between pretest and posttest results using a matched pairs t-test (Guilford 1965). The results are shown in table 1.

TABLE 1. The t-Test of the Differences Between Pretest and Posttest Scores.

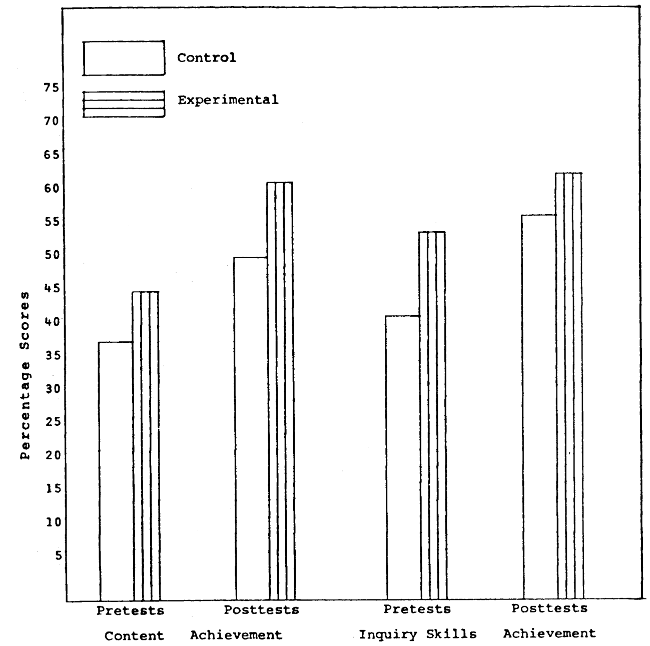
Variable	*t*
Cognitive Development	5.227
Content Achievement	13.548
Inquiry Skills Achievement	6.356
Intelligence Quotient	2.794

A graphic analysis of the data (fig. 1) indicates an increase in all four parameters from the beginning to the end of the experimental treatment. Furthermore, these gains were found to be significant at less than the 0.01 level of confidence.

In the second phase of data analysis, content and inquiry skills achievement of the experimental group is compared to the control group as shown in figure 2. The experimental group has a 17.4% increase in content achievement; the control group has an 11.8% increase.

On inquiry skills achievement the experimental group pretested far superior to the control group, therefore providing the experimental group with less opportunity for an increase on the EIB. The school system from which the experimental group was sampled has maintained an inquiry-centered science teaching program in the first eight grades since 1965. The superior proficiency of the experimental group on the EIB could perhaps be attributed to that inquiry teaching program. The school system's philosophy that professes inquiry as the teaching methodology could also influence the progress of inquiry development. The control group showed a greater pretest to posttest gain than the experimental group. We believe, however, that difference reflects the initial difference in pretests. Though both groups showed significant increases in inquiry skills the experimental group posttested 4.7% higher than the control group. The pretest to posttest gain of the experimental group on the EIB proved to be a significant ($t=6.356$) increase at less than the 0.01 level of confidence.

FIGURE 2. COMPARISON OF PRETESTS AND POSTTESTS PERCENTAGE MEANS OF CONTENT ACHIEVEMENT AND INQUIRY SKILLS ACHIEVEMENT



Conclusions

Data in table 1 and figures 1 and 2 support these conclusions:

1. The inquiry teaching method does promote cognitive development of high school biology students in the experimental group. On pretests of intellectual development, 59.8% of the sample had entered either the transitional period between concrete and formal operations or the formal operational period. After the inquiry treatment 71.7% of the sample had at least entered the transitional period.

2. The inquiry teaching method did increase content achievement in the subjects of this research. The mean score of the experimental group increased significantly when measured with the "Biology Content Examination." These gains proved greater than the control group's gain in content achievement as measured by the *Comprehensive Final Examination.* Both instruments measured learned conceptual and factual knowledge.

3. The inquiry teaching method does enhance inquiry skills achievement. Subjects in the experimental group exhibited significant gains in formulating problems, formulating hypotheses, using science literature, designing an experiment, interpreting data, and synthesizing new knowledge as measured with the "Explorations in Biology."

4. The inquiry teaching method does produce gains of IQ scores as measured with the *Short Form Test of Academic Aptitude* level five. The mean score increased from 106.68 to 108.83 with standard deviations of 12.51 and 12.54, respectively. This gain proved to be significant at less than the 0.01 level of confidence. In other words the experimental group as a whole gained 2.15 points from pre- to post-IQ tests which proved to be significant. We consider the fact that the nearly identical pre- and posttest standard deviations to be important. The entire group moved upward even though the variability within the group remained constant.

Recommendations

This research provides evidence to support the conclusion that the inquiry teaching method does increase intellectual development, content achievement, inquiry skills achievement, and scores on IQ tests. The results of this study suggest new questions for further research.

1. How completely are science programs throughout the country implementing the inquiry teaching methods? How are non-science courses employing the inquiry teaching methods? This research and research by Friot (1976), McKinnon (1971), and Stafford (1971) establishes the inquiry methodology as superior to the traditional lecture-demonstration methodology.

2. How is the intellectual level of the learner considered in curricula development? Are concrete operational students engaged in concrete experiences, concrete content, and concrete teaching procedures? How are educators involved with intellectual development? Research (Lawson and Renner 1975) has shown that not until the students become formal operational do they begin to demonstrate understanding in formal operational concepts. Other research (Sheehan 1970) has shown that students who have entered the formal operational period demonstrate higher levels of achievement while in school if they are taught concretely as opposed to formally.

3. How can student ability and potential be accurately determined with conventional IQ tests? How is a student's IQ affected by a traditional teaching method? IQ scores have long been exploitative indices of a student's intellectual profile. Is that statistic an accurate indicator of mental abilities or is there in existence better instruments to measure intellectual capabilities?

The answers to these questions could have a profound and constructive influence in educational curricula development and implementation.

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