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THE DIRECT TEACHING OF CRITICAL THINKING IN GRADES FOUR THROUGH SIX.

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SCIENCE UNITS CONSTRUCTED TO DIRECTLY TEACH CRITICAL THINKING ARE COMPARED WITH CONVENTIONAL SCIENCE UNITS FOR EFFECTIVENESS IN THE TEACHING OF CRITICAL THINKING. THE SAMPLE INCLUDED 1,554 FOURTH, FIFTH, AND SIXTH GRADE STUDENTS TAUGHT BY 65 TEACHERS IN FIVE DIFFERENT SCHOOL SYSTEMS. TEACHERS OF THE 469 STUDENTS IN THE RESEARCH GROUP WERE PERMITTED TO MODIFY TECHNIQUES IN THE UNITS DEVELOPED FOR THE STUDY. THE TEACHERS OF THE 651 STUDENTS IN THE EXPERIMENTAL GROUP USED THE UNITS AS WRITTEN. THE TEACHERS OF THE 434 STUDENTS IN THE CONTROL GROUP TAUGHT THE CONCEPTS INCLUDED IN THE UNITS, BUT USED THEIR USUAL TEACHING APPROACH. STUDENTS WERE PRETESTED AND POST-TESTED WITH UNIT ACHIEVEMENT TESTS AND A TEST DESIGNED TO MEASURE CRITICAL THINKING SKILLS. ANALYSIS OF VARIANCE AND COVARIANCE WERE USED TO COMPARE THE ACHIEVEMENTS OF GROUPS. PUPILS IN ALL GROUPS MADE SIGNIFICANT GAINS IN SUBJECT MATTER INFORMATION. ALL BUT THE FIFTH GRADE CONTROL GROUP MADE SIGNIFICANT GAINS IN CRITICAL THINKING SKILLS. THE AUTHOR CONCLUDED THAT CRITICAL THINKING CAN BE TAUGHT MORE EFFECTIVELY WHEN STUDENTS ARE GIVEN DIRECT TRAINING IN THE METHODS OF SCIENCE. THIS ARTICLE IS PUBLISHED IN THE "JOURNAL OF RESEARCH IN SCIENCE TEACHING," VOLUME 1, ISSUE 4, 1963. (AG)

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CONTENTS

- Prefa[illegible] 287
- Shel[illegible]es Foundation Helps NARST 287
- Patro[illegible] 288
- Comm[illegible]al Criticism
  - M[illegible] Guidelines for Research: *Alan H. McGowan* 289
  - Sc[illegible] Education—A Scholarly Discipline?: *Stephen S. Winter* 290
  - Gr[illegible] Evaluation of New Curricula: *Eugene C. Lee* 291
  - Str[illegible]s for Research: *James J. Gallagher, Rodney F. Mansfield, and William R. Snyder* 292
- Curriculum Evaluation by Means of Behavorial Objectives: *Henry H. Walbesser* 296
- The Effectiveness of a Unified Science in the High School Curriculum: *Irwin L. Slesnick* 302
- A Concept of Matter for the First Grade: *Herbert D. Thier, Cynthia Ann Powell, and Robert Karplus* 315
- The Direct Teaching of Critical Thinking in Grades Four Through Six: *John M. Mason* 319
- Empiricism as a Function of Training in the Scientific Method: *Eugene H. Kaplan* 329
- Teaching for Critical Thinking in High School Biology: *William Kastrinos* 341
- Short Reports
  - Evaluation of an Auto-Instructional Program in General College Chemistry: *James E. Banks* 351
  - An Evaluation of the Chemistry Topics in the BSCS Blue Version: *Burton E. Voss* 352
- Improving Science Education in the United States: *Claude W. Gatewood and Ellsworth S. Obourn* 355
- Author Index 401
- Volume Title Page i
- Volume Contents iii

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A report of a two-part study involving an in-service instructional program designed to develop lesson plans for the teaching of critical thinking and the experimental evaluation of the teaching units produced.

The Direct Teaching of Critical Thinking in Grades Four Through Six

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Introduction

This study originated at the request of a group of Michigan school administrators and curriculum supervisors from Dearborn, East Lansing, Flint, Grosse Pointe, Lansing, and Pontiac. This group, known as the Interschool Committee on Evaluation and Instruction, had been engaged for a number of years in studying various facets of critical thinking and ways to improve instruction.[1,2] The writer was asked by the committee, in the fall of 1957, to outline a plan for the improvement of science instruction in grades K–6 with special emphasis on the direct teaching of critical thinking. The result of this request was the formulation and the implementation of the present study which was concerned mainly with the development and with the determination of the efficacy of science units for grades 4–6. Units were also developed for grades K–3. However, no attempt was made to evaluate the effectiveness of these units.

Need for the Study

A review of the literature indicates that educators for more than thirty years have been stressing the need for instruction that emphasizes the methods of science.[3–6] A review of the literature also shows that these methods have not been implemented to any appreciable extent in the secondary schools. One may infer from these studies, comments from teachers, personal observations, and the lack of published evidence to the contrary that teaching for the development of critical thinking skills is seldom an integral part of elementary science programs. Such a review also indicates that there are disagreements as to how scientific methods are acquired.[7] The evidence appears to favor the direct approach to teaching the abilities inherent in problem-solving as opposed to the methods that are not focused directly upon these components.[8–11]

However, as pointed out by Dunfee and Greenlee,[12] there is need for much more research in order to determine the extent to which science instruction contributes to the development of critical thinking.

In addition to these problems, there are several other observations that indicate the need for research studies in elementary science instruction. The teaching of science in the elementary schools throughout the country varies from almost no science instruction or science integrated with social studies to well structured and efficiently implemented programs.[8,12–14] The nature of the science offerings also varies greatly in regard to objectives, subject matter content, and methods of teaching. It appears that little has been accomplished toward the solution of the problems associated with scope and sequence of materials. Consequently the same topics, without due cognizance of the spiral development of concepts, are treated much the same at different grade levels. It is also to be noted that various educators[12] have pointed out that the teacher's feeling of insecurity in handling

science is one of the most frequent reasons that teachers give for not stressing science in their teaching.

Overall Design of the Study

The study covered a two-year period. The first year was devoted to the preparation of science units by teachers in the participating schools (Dearborn, East Lansing, Grosse Pointe, Lansing, and Pontiac, Michigan). This was accomplished by conducting an in-service seminar program in each school. In the second year, the units were taught in the same schools under experimental conditions. In order to show the features and the results of the undertakings each year, this paper is divided into two parts. The first is concerned with the in-service seminar program and the second describes the experimental phase of the study.

Part I

The In-service Seminar Program

Introduction

The in-service seminar phase of the study began in the fall of 1958 and continued through the school year. The seminars were conducted as a part of Michigan State University's Continuing Education Program and carried two graduate credits per term. This feature was deemed desirable by the Interschool Committee since it provided a means for some of the teachers to meet certain local requirements for salary increases and/or additional academic experiences.

Purposes of In-service Program

The main purpose of the in-service seminar program was the development of science lesson plans for the direct teaching of the components of critical thinking in grades kindergarten through six. Other purposes were to familiarize the teachers with the components of critical thinking and with the so-called scientific attitudes and to increase their content knowledge in the areas in which lesson plans were to be developed.

Selection of the Teachers

It had been planned originally to have the members of the seminar in each school selected by the administrators in the respective schools. However, since credit was to be offered, it was agreed that a general announcement would be made and that interested teachers could enroll. There is no record to indicate whether the participants were those that had been approached directly by administrative personnel or had enrolled because of their own interest. The groups that were finally formed varied as to grade level, backgrounds, interests, and abilities. Ninety-three teachers in the five school systems participated in at least two of the three terms during the year. The number of teachers from each school was: Dearborn 28, East Lansing 13, Grosse Pointe 15, Lansing 18, and Pontiac 19.

Organizational Plan and General Assumptions

The same organizational plan was followed with the teachers in each of the five participating schools. The teachers in each school constituted a seminar group and met for a two-hour period each week for ten weeks each term. The study ran for three terms. The time of meeting was left to the teachers in each school. Dearborn, Grosse Pointe, and Lansing had their meetings at 4 pm and East Lansing and Pontiac met in the evening. The writer scheduled his time so that he would be able to meet with the respective groups six of the ten meetings per term. The other four meetings each term were in charge of local personnel.

In an effort to orient the teachers, the instructor spent considerable time in clarifying the basic assumptions which were considered significant for the development of science units. Some of these assumptions were: (*1*) children should have planned experiences in science rather than incidental experiences; (*2*) children should have direct experiences with both the content and the methods of science; (*3*) the skills and at-

titudes of science are capable of identification and situations can be set for giving pupils direct training for the acquisition of these skills and attitudes; (*4*) the elementary science program should provide for adequate scope and sequence in grades K–6; and, (*5*) teachers should strive for greater competency in both subject matter and in instructional techniques.

Several meetings were devoted to familiarizing the teachers with the nature of critical thinking. For the purpose of this study, it was assumed that critical thinking may be described as a process which is characterized by such components as the ability to (*1*) recognize and define problems, (*2*) select information relevant to solving a problem, (*3*) formulate possible solutions of a problem, (*4*) test hypotheses, (*5*) form conclusions validly, and (*6*) recognize basic assumptions. It was stressed that these are not steps which must be followed in a sequential pattern and that one may think critically and arrive at valid conclusions without employing all of these skills for every situation. It was further assumed that such phrases as critical thinking, problem-solving, scientific methods, methods of science, and scientific thinking may be considered as synonyms since they are used by many present day investigators to describe the same abilities.[8]

Seminar Activities—Preparation of Lesson Plans

Seminar activities included lectures, discussions, independent and group study, and writing. In writing lesson plans, an attempt was made to construct the lessons according to the following specifications.

1. The plans were to be detailed in every respect. Directions were to be given for the exact situations and/or activities in which the teacher and pupils were to participate.

2. The plans were to be designed to develop specific concepts in a framework that would emphasize training in some aspect or aspects of critical thinking. That is, both subject matter and problem solving were to be stressed with the techniques of presentation providing actual situations for training in critical thinking skills. The authors were to attempt to set situations that would provide experiences in problem recognition, the collection of relevant data, hypotheses formation, devising, and testing hypotheses by a variety of means, such as experimentation and demonstrations, and the formulation of tentative conclusions. Critical thinking was not conceived to be a step by step process and the above order of skills was not to be followed necessarily in writing the plans. The principal task was to set situations for each lesson which would provide training in some aspect or aspects of the processes involved in critical thinking including the so-called scientific attitudes.[15–21]

3. The lessons were to be varied according to an individual's approach for motivation, for collecting data, for individual and group work, and for other desirable features for classroom instruction. That is, within the framework of the above features, teachers were encouraged to be creative in the construction of the lessons.

Lesson plans were constructed individually. Teachers had to spend a great deal of time outside of the regularly scheduled seminar time in studying content material and in actual writing. Some teachers tried their ideas either before formal writing or after the first draft. The plans were submitted to the writer for review and typing. They were then returned to the authors for further work and/or revision. In some instances, they were used for the purpose of instruction, criticism, and evaluation in the seminar period. The teachers in a given school developed lesson plans only for the unit which their group had selected as their area of interest. As lesson plans developed, some effort was made by the instructor to exchange the lessons prepared in one school with those prepared in other schools. This proved to be a good motivating technique and a means for establishing common goals between the teachers at the various schools.

Some of the units and/or lessons were developed as new materials. In other in-

stances, they were, in part at least, revisions or adaptations of materials already existing as a part of the science curriculum of the school.

Five mimeographed teaching units were constructed during the year. The units produced by the participating schools were: Space-Dearborn, Water-East Lansing, Astronomy-Grosse Pointe, Atmosphere-Lansing, and Physical Phenomena-Pontiac.

Recommendations

The recommendations and opinions which follow are based on the writer's experience as the instructor for the in-service seminars. They are offered for those who may be interested in future work of this nature.

1. In a study of this kind, the participants should be selected very carefully. Such things as interest, adequate science preparation, creativeness, demonstrated writing ability, knowledge of teaching techniques, and willingness to be receptive to ideas different from one's own should be some of the characteristics sought for in those that are selected to undertake the development of new curricular materials.

2. The offering of academic credit for such an undertaking should be only incidental to the project. It would be much better to eliminate academic credit as it tends to bring into focus many of the undesirable features associated with grading individuals. The goals of the individuals engaged in such an undertaking should be something more than securing additional credits so that they may qualify for a pay increase or some other extrinsic standard.

3. It would be advisable to have some kind of formal instruction for an entire group on a specific subject matter area rather than have the participants try to secure such information through independent study. That is, for one to write lesson plans successfully, he needs training in content material. Besides using university instructors for such training, other methods, such as securing local resource people and using well prepared high school teachers should be tried.

4. In conducting a study such as this, there should be adequate personnel and local responsibility for the group's work in a specific school system. There are many psychological and/or administrative reasons for a large measure of responsibility resting at the local level, such as familiarity with the philosophy of the school, rewards particular to a specific system, the ease of scheduling and of handling a variety of problems which might arise, and the desirability of local stimulation and leadership that will carry on after the completion of a specific research or developmental study.

5. The task of stimulating and directing classroom teachers in the writing of lesson plans designed to implement the skills in critical thinking is a most difficult one and there is no one best method to accomplish the job. There will be periods of frustration and these are to be expected if any real problem solving occurs in the group itself. However, every effort should be made to keep such periods at a minimum. The writing of such studies should be as nondirective as possible, but there may be times when it is necessary, in order to lessen frustration, to be very directive about how to do a given task.

6. Some provision should be made to free teachers from other responsibilities when they are selected to engage in curriculum studies during the regular school year. One cannot expect teachers to do their best work after having worked a full day or when they have other responsibilities to discharge. One recommendation would be to conduct such a study in the summer with regular pay for such work.

7. Curriculum studies such as this should have representation at each grade level and efforts should be made to keep the entire staff informed as to the progress of the work. Lesson plans should be tried out in classroom situations before publication for general distribution.

8. A project such as this one should be tied intimately with a school's research program. Evaluation instruments should be developed along with curriculum materials.

It would also be desirable to correlate such a study with resources of the system including equipment, library facilities, and other things necessary for the proper implementation of the program.

Part II

The Experimental Phase

The experimental phase or the actual teaching of the materials that had been prepared during the in-service seminars in 1958–59 began in the fall of 1959. The steps taken in getting the study underway were as follows. An announcement was made in each school system that a meeting was to be held to discuss the purpose and design of an experimental study that was to be carried on in the various school systems. Interested teachers were invited to attend the meeting. At each meeting, the development of the materials, the main hypothesis to be tested, and the kinds of testing to be attempted were reviewed. The method of selection was left to administrative decision in each school system. In some cases, selection was by lot and in others by administrative designation after consultation with the teachers. It is the writer's opinion that the method or methods used to select the teachers in this study did not bias the study any more than other variables, such as teacher interest, personal prejudice for or against a given technique, previous science training and teacher ability.

Design of the Study

The study began in December 1959 and ran through the remainder of 1959–60 school year. The schools participating in the study were Dearborn, East Lansing, Grosse Pointe, Lansing, and Pontiac. The materials to be used were the five units (Atmosphere, Astronomy, Physical Phenomena, Space and Water) which had been constructed by the members of the 1958–59 in-service seminars. There were three groups of teachers and their respective students taking part in the study. The groups were designated as Research, Experimental, and Control. These groups were established for all grades K–6. However, no objective evaluation was attempted for the pupils in kindergarten through three due to the lack of time for the development of evaluation instruments. The statistical findings of this study are limited to grades four through six.

The teachers who had been members of the 1958–59 seminar and who had expressed a desire to be a part of the 1959–60 study and their pupils constituted the group designated as the Research Group. These teachers operated on the understanding that they would use the materials, but were free to make modifications as desired in techniques for implementing critical thinking skills.

The group designated as the Experimental Group was composed of the pupils of teachers who participated in the study with the understanding that they would use the material as printed.

The Control group of pupils was directed by teachers who agreed to teach for the same concepts as in the units used by the Experimental teachers. However, they were to follow their usual type of teaching procedure.

Groups in the Study

Table 1 shows the teachers and pupils from the respective schools that constituted the groups in the study that were used for comparative purposes.

Tests Used in the Study

The test designed to measure critical thinking skills was constructed by Dr. Clarence Nelson, a specialist in evaluation with the Office of Evaluation Services, Michigan State University. This instrument was adapted for pupils in grades four through six. The instrument was administered by the teachers in the study as a pre-test in the fall of 1959 and as a post-test at the close of the school year 1960.[22]

Factual tests for grades four, five, and six were developed for each of the five units used in the study by the author with the assist-

TABLE 1
Teachers and Pupils by Grades and Groups

	Research		Experimental		Control	
	T[a]	P[b]	T	P	T	P
Fourth Grade						
Dearborn	0		0		3	58
East Lansing	0		1	25	0	
Grosse Pointe	1	20	0		1	27
Lansing	3	85	3	67	2	53
Pontiac	0		4	90	0	
Total	4	105	8	182	6	138
Fifth grade						
Dearborn	3	71	5	124		
East Lansing	1	26	2	37	1	26
Grosse Pointe	0		0		2	51
Lansing	0		3	66	2	54
Pontiac	3	79	1	29		
Total	7	176	11	256	5	131
Sixth Grade						
Dearborn	6	134	5	112	3	74
East Lansing	1	22	1	21	1	24
Grosse Pointe	0		1	22	2	51
Lansing	0		2	58	1	16
Pontiac	1	32				
Total	8	188	9	213	7	165

[a] Number of teachers.
[b] Number of pupils.

ance of Dr. Joseph Jackson, Mr. George Stuteville, and other members of the staff of the Evaluation Section of the Dearborn Public Schools. Each factual test was administered as a pre-test at the beginning of a Unit of study and as a post-test at the completion of the study. Directions were distributed to all teachers for administering the tests and approximate dates for beginning and ending the units. All tests were controlled and the teachers did not have access to the keys for the tests.

The tests were assumed to have curricular validity since Dr. Nelson was a specialist in the area of critical thinking and the other writers were intimately associated with the development of the content materials used in the study.

IBM answer sheets were used for pupil responses for all the tests. The sheets were returned to the author. All answered sheets were then machine scored and later hand checked for accuracy.

Hypothesis Tested and Statistical Methods Used in the Study

Comparisons were made between Research and Experimental, Research and Control, and Experimental and Control groups on all instruments at the fourth, fifth, and sixth grades. The hypothesis held for each comparison made in the study was that achievement is independent of instructional method and materials. That is, the mean achievements of the pupils in the compared samples are equal.

The technique illustrated by Johnson[23] for analysis of variance and covariance with one independent variable was used to test the above hypothesis. With each analysis, the independent variable was the pre-test score relative to the specific test at the designated grade.

The test of significance used in each analysis was the F-test. When the hypothesis was accepted, it was inferred that the

difference between the mean achievements of the pupils in the samples could be attributed to chance. Therefore, one instructional technique was assumed to be just as effective as another method.

The hypothesis was rejected when this test indicated significance at the 0.01 or 0.05 level of confidence. When the hypothesis was rejected, it was inferred that the difference between the mean achievements of the pupils in the samples could hardly be due to chance alone. This difference was assumed to have been the result of the instructional techniques since in the analysis the one independent variable was controlled by a covariance adjustment.

To determine which method of instruction had produced the significant difference when the hypothesis was rejected, the means of the samples were adjusted for the sample difference on the independent variable in accordance with the technique suggested by McNemar.[24] The technique used in teaching the pupils in the sample having the higher adjusted mean was considered to have been the more effective method of teaching.

Critical ratios were also calculated to test the significance of the difference between initial and final sample means on each test for each group at each grade level.

Results of Comparisons between Groups-Fourth Grade-Critical Thinking

The F-tests were significant for the comparisons between the Research and the Experimental groups and the Research and the Control groups on the critical thinking instrument. The adjusted mean for the Research group in each analysis was higher than the compared group and it was therefore inferred that the Research group had increased significantly in the ability to think scientifically. The F-test was not significant in the comparison between the Experimental and Control groups. From this finding, it appears that the materials as used with the pupils in the Experimental group did not produce any greater change in pupil ability to think scientifically than the materials used in the Control group.

One may infer from the results of the fourth grade comparisons that the teacher was the significant factor in producing significant change in pupils' ability to think critically. This inference is supported by the observation that the adjusted means for Research group were greater than the means for either the Experimental or Control groups. Since the teachers in the Research group were those that had had experience in developing the materials, one could infer that their experiences had contributed to their ability to teach the skills.

Fifth Grade—Critical Thinking

The results of the analysis for the fifth grade comparisons with respect to ability to think critically show that the Experimental group was significantly higher at the end of the year than either the Research group or the Control group. The results also show the Research group was higher than the Control group. These findings indicate that the materials for the fifth grade were effective for the direct teaching of the skills inherent in critical thinking.

It is interesting to note that the Research group did not excel the Experimental group as was the case in the fourth grade. Apparently the previous experience of the Research teachers in developing materials did not make them necessarily better qualified to teach the materials.

Sixth Grade—Critical Thinking

The F-test was not significant for any of the sixth grade comparison with respect to critical thinking skills. This would indicate that the materials, as developed for this grade, were not any more effective in setting situations for the direct teaching of critical thinking than the procedures used by the Control teachers. It also may be inferred that the previous experience of the teachers in the Research group was not a significant factor in the implementation of the units

designed for the direct teaching of critical thinking.

Fourth Grade—Factual Information

The comparisons at the fourth grade on the factual tests showed that the Research group did significantly better than the Experimental group on the units on Astronomy, Physical Phenomena, Space, and Water, and also better than the Control group on Space and Water. The Control group did better than the Experimental group on the units on Astronomy, Physical Phenomena, and Water.

Fifth Grade—Factual Information

At the fifth grade, the Experimental group on the factual tests did significantly better than the Research group and the Control group on every unit. The Research group did better than the Control group on all units with the exception that there was no significant difference between the Research and Control groups on the unit of Water.

Sixth Grade—Factual Information

The sixth grade comparisons indicated that the Research group did significantly better than the Experimental group on the units on Atmosphere and Astronomy. The Control group did significantly better than the Experimental group on the unit of Astronomy.

Results with Respect to Pupil Progress

The test results from the administrations of the critical thinking instrument and from each of the unit tests were used to determine student progress with respect to the acquisition of critical thinking skills and of factual information. In addition to the analyses made of the comparisons between groups, critical ratios were calculated to test the significance of the difference between initial and final sample means on each test. The ratios for each group at each grade level on all the instruments were statistically significant with the exception of the Control group on the critical thinking test at the fifth grade level.

Tentative Conclusions

The experimental phase of the study seems justified educationally in that the pupils in all groups at the grade levels evaluated made significant gains in subject matter information. Significant gains were likewise made by all the groups in critical thinking skills with the exception of the Control group in the fifth grade. Besides these gains in pupil achievement, the science supervisors in the various schools indicated, in personal conversations, that teachers appeared more interested in science and that science was being stressed more than in previous years. The tally of teacher responses to a questionnaire item designed to elicit information about emphasis upon science supported the above observation. It was apparent that even the Control teachers had placed more stress on science. This is an interesting concomitant of many experimental studies. It would appear that there are conditions inherent in an experimental study which arouse the personal motivation of the teachers involved in the study. This is what an investigator should desire as each group of teachers should do the best possible job with the particular techniques that are employed in teaching the pupils.

The results of pupil achievement on the critical thinking instrument add support to the belief that the components of scientific thinking may be concomitants of science instructions. This was evidenced by the significant gains made by the pupils in the fourth and sixth grade Control groups. This finding differs from the results of several other studies[25] and emphasizes the need for additional studies. It seems to this investigator that the point of view that critical thinking skills do not result from contact with science instruction by qualified science teachers is open to question. Personal observation would indicate that many excellent scientists have acquired their abilities in classrooms where problem-solving skills were

not directly taught for. Care should be exercised in drawing generalizations without some indication of the quality of the science teacher. It is possible that the teacher is a most significant factor in any teaching situation and that good science teaching will produce significant changes in pupil ability to think scientifically even when the components are not directly stressed as such.

The fourth grade Research group did significantly better on subject matter than the Experimental and Control groups and the Control group likewise did better than the Experimental group in subject matter achievement. At the sixth grade the Research and Control groups did better than the Experimental group. It would appear at these two grade levels that the Experimental groups did not profit as much as the Control groups with respect to science content. However, the Research teachers who used the same materials produced as great or greater gains than the Control teachers so there is some evidence to indicate that the materials were more effective than the Control procedures.

The strongest evidence for the efficacy of the units resulted from the analysis of the fifth grade data. Since both the Experimental pupils and the Research pupils did significantly better than the Control pupils, the materials at this grade appear very effective for teaching critical thinking and science content.

The comparisons between the various groups on the Critical Thinking instrument show that some of the materials, as developed for this study, may be more effective for teaching critical thinking and science content than procedures that are not designed specifically for the direct teaching of content and methods of science: However, it is to be noted that all the materials did not produce significant differences between groups. Continued research is needed in the development of materials for the direct teaching of critical thinking skills at all levels of instruction.

The results of the comparisons at the fourth grade appear to indicate that the teachers who had had experience in developing the materials were more effective in using the materials than those who had not had this experience. However, this condition did not hold for the fifth and sixth grade teachers. Therefore, it may be concluded that in-service seminar experiences in building units designed to directly teach for critical thinking skills do not necessarily better prepare teachers to implement these skills in classroom situations.

It seems justifiable to state that the results of this study lend support to the idea that self-contained units designed to teach directly for both content and critical thinking skills may be effective aids for teaching those objectives.

Educational Implication

In the light of the results of this study, the following educational implications seem reasonable and justifiable.

1. The ability to think scientifically can be a concomitant outcome of science instruction.

2. The ability to think scientifically can be taught more effectively when students are given direct training in the methods of science than when they do not receive such training.

3. Problem-solving can be an effective method for teaching both facts and skills inherent in the methods of science.

4. It is possible to construct effective materials for the direct teaching . . . of the methods of science.

It is interesting to note that the above conclusions are the same as those drawn from a study with college students.[7]

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