R E P O R T   R E S U M E S

ED 016 608 56 SE 003 325

THE EFFECTIVENESS OF FOUR VARIATIONS OF PROGRAMED SCIENCE MATERIALS.

BY- GORDON, JOHN M.
MICHIGAN ST. UNIV., EAST LANSING

REPORT NUMBER BR-5-0747 PUB DATE 67
GRANT OEG-7-32-0410-256
EDRS PRICE MF-$0.25 HC-$1.68 40P.

DESCRIPTORS- *AUDIOVISUAL AIDS, *ACADEMIC ACHIEVEMENT, *GRADE 7, *INSTRUCTION, *PROGRAMED INSTRUCTION, *SECONDARY SCHOOL SCIENCE, COGNITIVE DEVELOPMENT, ELECTRICITY, PHYSICAL SCIENCES, UNITED STATES OFFICE OF EDUCATION, NATIONAL DEFENSE EDUCATION ACT, TITLE 7 (NDEA), LANSING, MICHIGAN, WEST JUNIOR HIGH SCHOOL

INVESTIGATED WERE CHANGES IN THE PERFORMANCE OF SEVENTH GRADE STUDENTS AS A RESULT OF EXPOSURE TO A SYMBOLIC SCIENCE PROGRAM IN ELECTRICITY MODIFIED BY THE ADDITION OF SEVERAL TYPES OF CONCRETE EXPERIENCES. POSSIBLE RELATIONSHIPS BETWEEN THE DIFFERENT TYPES OF EXPERIENCES AND CHANGES IN HIGHER LEVELS OF COGNITIVE FUNCTIONING AND LINGUISTIC AND QUANTITATIVE APTITUDE WERE ALSO EXPLORED. FOLLOWING A PRETEST FOR KNOWLEDGE OF MAGNETISM AND ATOMIC STRUCTURE, 16 CLASSES IN A JUNIOR HIGH SCHOOL WERE RANDOMLY ASSIGNED TO ONE OF FOUR TYPES OF PROGRAMED INSTRUCTION. THE VARIATIONS RESULTED FROM SUPPLEMENTING A BASIC LINEAR PROGRAM WITH DIRECT LABORATORY EXPERIENCE, SILENT MOTION PICTURE DEMONSTRATIONS, OR STILL PICTURE DEMONSTRATIONS. FOUR CLASSES OF STUDENTS WITH LEARNING DIFFICULTIES WERE ALSO ASSIGNED TO THE DIFFERENT MODES OF INSTRUCTION. POST-TESTS WERE DEVELOPED SPECIFICALLY FOR EACH MODE OF INSTRUCTION. EACH INSTRUMENT INCLUDED QUESTIONS WHICH TESTED THE STUDENT'S (1) KNOWLEDGE OF THE SUBJECT, AND (2) ABILITY TO RECOGNIZE PRINCIPLES, SOLVE PROBLEMS, AND TRANSFER FROM ONE MODE TO ANOTHER. FINDINGS WERE INTERPRETED THROUGH ANALYSIS OF VARIANCE. NO DIFFERENCES WERE FOUND IN THE PERFORMANCE OF EITHER REGULAR OR ADJUSTED CLASSES DUE TO INSTRUCTION MODE, TEST FORM, OR TRANSITION FROM ONE MODE TO ANOTHER. NO DIFFERENTIAL EFFECTS ON THE SUBTESTS REPRESENTING TYPES OF HIGHER COGNITIVE FUNCTION WERE DETECTED. THE LACK OF DIFFERENCES BETWEEN THE MODES OF INSTRUCTION NEGATED ANY TEST OF RELATIONSHIP BETWEEN APTITUDE AND THE ABILITY TO DEAL WITH CONCRETE EXPERIENCES. (AG)

ER-5-0747
PA 56

The Effectiveness of Four Variations of Programed Science Materials

Dr. John M. Gordon Jr., Principal Investigator

Title VII Project Number ORD 2400

National Defense Education Act of 1958

13/67
RB

Grant Number OE-7-32-0410-256

Dr. John Barson, Sponsor

Michigan State University, Grantee

The Research Reported Herein was
Supported by a Grant from the
U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Office of Education

ABSTRACT

Purpose: A principle, fundamental to science education, audio-visual theory, and child development, states that children should be given the opportunity to gain knowledge of the world about them from direct experience. Programed instruction, being primarily an abstract, symbolic exercise, has been criticized for not adhering to this rule. The purpose of this study was to assess the effects of supplementing a basically symbolic science program with more concrete representational forms or modes; direct experience, silent motion pictures, and still pictures. The criterion test was also developed in the same forms to ascertain any difficulties in the transition from one more or less abstract form to another. The differential effects on more complex cognitive skills were explored, as well as the possible relationships between linguistic and quantitative aptitudes and the ability to acquire the information from these varying forms.

Procedures: Four separate forms of a basic linear program, containing the same information and six typical experiments in electricity, were developed by representing these experiments in direct laboratory experiences, silent motion picture demonstrations, still picture demonstrations, as well as symbolic forms. The criterion test was also generated in these four forms. Sixteen seventh grade science classes were randomly assigned to a single program-test form combination. Four adjusted classes were also given one of the program forms. The criterion test included knowledge, principle recognition, and problem-solving items. Linguistic and quantitative aptitude stanines were also collected to assess any relationships between aptitude and ability to utilize any of the representational forms. Criterion performance was analyzed separately by variance breakdown and correlational techniques. Item frequency counts were also studied.

Results and Conclusions: No differences ~~were found~~ in ~~the~~ performance ~~by~~ for were found of either regular or adjusted classes due to either instruction mode or ~~program form~~, test form, ~~or the transition from one more or less abstract form to another.~~ There were ~~also~~ no differential effects on the test sections ~~subtests~~ representing types of higher cognitive functioning. The lack of in most mode ~~modality~~ differences negated any ~~real~~ test of the relationship between aptitude and the ability to deal with ~~more or less~~ concrete representation.

The lack of differences suggest one or a combination of the following explanations:

1) Seventh grade students are capable of dealing with abstractions and do not need the more concrete form, 2) the experiments were already within their direct experience so they did not need to return to these experiences to comprehend, 3) the concepts and principles of electricity are at such a level of abstraction that partial understanding is the best one expected at this age (note: some of the teachers professed difficulty), 4) the use of words both to direct the student through the experiments and as expository material between experiments may have negated any possible gain from the more concrete representations, 5) the low reading abilities, known to exist with these students, might have hindered comprehension using all representational forms. It seems that given the right set of conditions; developmentally apt, experienced students who can read, that information transmitted in the symbolic form such as programed instruction may be as effective as more concrete experiences, plus being less expensive and less time consuming.

Summarizing, the generality of the "experience" principle is questioned. The principle should probably be replaced by a set of conditional statements that delineate such characteristics as age of the learner, abstraction of the task, and probability of the example of being in the learner's experience.

Acknowledgments

The author wishes to acknowledge the cooperation and patience of the following persons: Dr. John Barson, Sponsor of the Project; Dr. Charles Schuller, Project Transmitter; Dr. Robert Brandou, Science Consultant; Mr. Thad Twarozynski of the Michigan State University Business Office; Seventh Grade Teachers Glen Baxter, Lloyd MacPherson, Robert Bailey, Ray Schaubel, Mrs. Rebecca Moore, and Mrs. Kathy Kolster; and student assistants Judith Smith and Kathleen Wood. In return, the author can only hope that these persons and other persons like them can benefit from the information collected and conclusions drawn.

I. Problem Section

A. Modality Decision Difficulty

1. In General Instruction

Perhaps the most fundamental, accepted, and practiced principle in science education is that "whenever possible, children should be given opportunity to gain knowledge of the world about them from direct experience" (Blough, 1960, p. 141). Reliance upon this overwhelming principle is so great that: 1) laboratory exercises and teacher demonstration are virtually unquestioned as instructional techniques, 2) millions of dollars have been spent for equipment, materials, and trips so that each child can gain firsthand knowledge of the wonders of science, and 3) no science teacher is complete without his bags of tricks plus carefully practiced legerdemain.

Also the instructional theorists, although they may be aligned with different camps, adhere, with slight alterations, to the principle. For example, Gagne (1965) has emphasized that "Instruction needs to be fundamentally based on the stimulation provided by objects and events--objects and events are the stimuli from which concepts are derived. Although instruction comes to depend heavily on verbal communication, the words merely stand for things that can be directly observed." (p. 272-3). In addition, Bruner (1964) has accepted Piaget's general notions of step-wise cognitive functioning and cited the need to "begin with an enactive representation--something that could literally be done or built and to move from there to an iconic representation--then it should be converted into a properly symbolic system." (p. 328).

These points of view can also be regarded as instances of Dale's (1946) more general notion which underlies his Cone of Experience, that the closer the instructional situation approximates reality the more effective the experience should be. This inclusive principle has long been the fundamental rationale for the use of audio-visual machines and materials.

Ausubel (1964), however, seems to be opposed to the general notion when he emphasizes that "the primary school child is by no means dependent on immediate concrete-empirical experience in understanding and manipulating simple abstractions or ideas about objects and phenomena." (p. 261). He does accept the natural progression of concrete to abstract in cognitive development but cautions "that once their meaning becomes firmly established as a result of this background of past experience, the child can meaningfully comprehend and use them without any current reference to concrete-empirical data." (p. 261).

Another slight deviation from the principle can be found in Bruner's (1966) latest work that describes children from four to seven years old becoming confused rather than enlightened by being able to see concrete materials. Showing them the different water levels in the conservation experiment brought forth more errors than seeing just the water being poured. "If the child customarily deals with things in terms of their image properties, though he may in fact have the language necessary to deal with them in a more powerful way, it must be that reckoning by the appearance of things inhibits his use of linguistic categories for dealing with the situation." (p. 15-16). He states powerfully that "Language provides the means of setting free of immediate appearance as the sole basis of judgment." (p. 16).

2. In Programed Instruction

Mechner's (1965) extensive review and critique of programing in science clearly emphasizes this need for direct experience. He opines that "concept formation in science teaching requires that the student make observations and perform experiments." (p. 480). Programs are, therefore, inadequate because they attempt "to teach interverbally, or by rote, concepts which should be taught by example or empirical reference." (p. 502). More specifically "they are not designed in the appropriate medium or response modality, i.e., to teach an aspect of engineering or experimental science without providing access to the relevant laboratory equipment." (p. 502-3). Gotkin (1964) also expressed the need for a change in modality when developing and testing programs for the culturally disadvantaged, concluding that "We were faced with the inability of children at the seventh grade level to cope with the iconic, let alone symbolic, representations." (p. [illegible]

B. Criterion Test Modality Difficulty

It became immediately apparent as the project research team studied the modality problem in terms of the acquisition or program stage that the criterion test also is subject to the same modality decision difficulties. The common paper and pencil variety of criterion task is als primarily in the symbolic form. As Gotkin stated it, "The issue of modali is complicated further by our limited knowledge as to the facilitation of the transitions from one cognitive level to the next." (Gotkin, 1964, p. [illegible] Or as Bruner put it, "How transitions are effected--from enactive represent tion to iconic, and from both to symbolic--is a moot and troubled question (1966, p. 14). Thus a criterion test, commonly in the symbolic form, pres a secondary or transition problem. It is possible that any gain from acqui the information in the more concrete-supplemented form might be eliminated due to the inability to translate from that form to the symbolic.

C. Two related problems come within the domain of this study. The first deals with the question of the interaction between modality and higher level cognitive functioning primarily those dealing with transfer and problem solving. Does one form of information enable the student to more readily generalize to similar situations?

The second question calls attention to the possible individual differences within the students that might influence their ability to acquire information from more concrete or abstract forms. Does the linguisticall apt student perform better when working symbolic tasks? And the opposite does the quantitatively apt student find the concrete experience more to his liking?

Although these questions are not the focus of the study, evidence wil be obtained which might offer a new perspective.

D. Overview and Purpose

What then is the communicative modality of science? Is it imperativ that the child have concrete classroom experience to acquire the selecte concepts and principles that constitute the scientific content? Are programs, which are mostly symbolic, as ineffective as Mechner says?

It was the purpose of this project to assess the effects of studying different forms of the same basic linear program on the performance of seventh grade students. These forms were developed by representing the six program experiments in four modes varying on the continuum from concrete to abstract. The representational modes selected were direct laboratory experience, silent motion picture demonstration, still pictu demonstration, and the wholly symbolic form. The criterion test was also developed in each of the four forms to test the effects of having to transfer from one modality to another. Other problems under investigation are: the effects of these modality changes upon higher levels of cognitive functioning, and the relation between linguistic and quantitative aptitude and the ability to learn from different modalities.

II. Related Research

The representational modality decision in the acquisition of concepts and principles is a crucial one for educatiors in the areas of science education, audio-visual theory, child development, and programed instruction. There has, however, been little and conflicting research done in any of these areas to help others in making these major instructional decisions. The most comprehensive study is now being completed by Allen and Filep (1964) who studied the relative effectiveness of visual and audio presentation modes in programs using non-concrete, concrete, and action process strategies upon seventh grade students. A preliminary paper given by Filep indicated that there were no differences due to variations in the visual presentation modes of printed verbal, still graphic, or motion pictures. This evidence conflicts with the cone of experience proposed by Dale and accepted by audio-visual aids advocators.

Irwin and Aronson (1958), however, did find support in that the subjects' performances differed on a visual and verbal criterion test dependent upon which presentation form, visual or verbal, they received.

Earlier, both Rulon (1933) and Vernon (1946) had found that sound films were more effective in promoting concept generalization but had no effect upon rote or memory for detail items.

Piaget's studies with children led him to postulate certain developmental levels which were supposed to have relevance for teaching school tasks. Junior high school students, the level dealt with in this study, were placed in the Formal Operation Stage. At this level the student is to be able to go beyond the immediate data and make hypotheses. Ausubel (1963) interprets this to mean that:

> "Beginning in the junior high period, however, children become increasingly less dependent upon the availability of concrete-empirical experience in meaningfully relating complex abstract propositions to cognitive structure. Eventually, after sufficient gradual change in this direction, a qualitatively new capacity emerges: the intellectually mature individual becomes capable of understanding and manipulating relationship between abstractions without any reference whatsoever to concrete, empirical reality." (p. 118).

Hedges and MacDougall (1965) supported Ausubel's notion of not needing reality and also did it with fourth grade students. They found no differences among the achievement of fourth grade classes using the programed materials plus laboratory experiments, classes using the same materials but only reading about the experiments, and classes using the material rewritten in textbook form with the teachers doing the experiments in demonstrations. Furthermore, Cunningham (1946), in a review of 37 different demonstration vs. laboratory approach concluded that laboratory experience could only be said to facilitate specific laboratory skills and not affect the general content being taught.

The kaleidoscope of studies that have touched upon the question acquisition modality present little and confusing evidence for such a widely accepted principle.

III. Objectives

This project was pursued in order to assess the effects of supplementing a basic symbolic linear program with different representational forms varying on a continuum from concrete to abstract. The different forms employed were on a continuum of concrete to abstract: direct laboratory experience, silent motion pictures, still pictures and wholly symbolic. The criterion test was also developed in these four forms in an attempt to discover any differences arising from the transition between the various representative forms. The criterion task was divided into items dealing with program knowledge, principle recognition, and solution of new problems to see if there were any individual influences of these different forms upon the cognitive functions represented by these tasks.

It was hypothesized that:

1) The more concrete the representation of the program information, the greater the overall criterion performance.

2) The more concrete the representation of the test information, the greater the overall criterion performance.

3) The closer the representative modes of the program and test form are on the concrete-abstract continuum, the greater the criterion performance. Put in more general words, the less the transition between modalities in the teaching and testing phases, the greater the performance.

Also of interest and thus far unpredictable are the following relationships: 1) Are there any differential effects resulting from the program and test forms variations on the cognitive functions represented by program information recall, principle recognitive and problem-solving items? 2) What relation is there between linguistic and quantitative ability and the capability to deal with the different forms of information

IV. Procedures

Approximately 500 seventh grade students at West Junior High School in Lansing, Michigan were used as subjects. West Junior is an urban school whose students come from all socio-economic levels. If there were any peculiar characteristic about this school's population, it might be said that there were fewer students representing the middle income level.

A teaching unit on the fundamentals of electricity was chosen to program because of the amenability to small laboratory tasks and the time placement in the general science course. A tentative list of concepts and principles to be taught was drawn up. (See Table 1.) Each of five seventh grade science teachers, a college teacher of science teachers the investigator, and two graduate students independently outlined what they preferred to be the instructional sequence to teach these objectives. Considerable variation resulted and each sequence was in some way unique. A major split developed between those who favored the student arriving at various conclusions (discovery) and those who supported the tell and show him (expository) approach. The classroom teachers tended toward the expository, feeling that the slow students' handicaps would be accentuated if they had to make too many inferences.

Table 1

Tentative List of Principles and Concepts in Program

I. <u>Principles</u>

a. Friction produces static electricity (electrical energy).

b. Magnetism produces electrical energy.

c. Chemical action produces electrical energy.

d. Like charges repel.

e. Unlike charges attract.

f. Charges move through conductors.

g. Charges do not move through non-conductors or insulators.

h. Different materials conduct to different degrees.

i. A week acid is a good conductor.

j. A voltaic cell is composed of two different conductors and a weak acid solution.

k. Zinc is more active than copper.

II. <u>Concepts not in Principles</u>

Circuit, ground, electroscope, galvanometer, coil, battery, lines of force, electromagnet.

Another, more subtle set of problems evolved from the occurrence of the varying sequences. First, as the lack of specificity and rationale within their proposed sequences had already demonstrated, some of the teachers admitted that they had not really understood electricity. If the teachers who have studied these fundamentals in "depth," don't understand, how can one expect the students to master them? In other words, some concepts in science, especially those which have no direct physical referent, are destined to varying "degrees of understanding" and should be recognized as such. Second, though not independent of the first, the fact that each teacher's sequence was in some way unique, raises the question as to whether there is one right or best sequence. This experience seems to support Bruner's (1964) contention "that no single ideal sequence exists for any group of children." (p. 334).

A compromise sequence, expository in nature, was accepted. Six laboratory-type experiences, which were common examples of the content, were incorporated into this sequence. A set of frames was written and rewritten around the experiments to the teachers' satisfaction. It was not feasible to test the program on a sample of students at that time because they had not been exposed to the prerequisite units which led to the chapter on electricity. In other words, there was no "true" sample target audience. Since the sequence is only taught once a year, it became imperative to rely on the teachers' judgments. The final form had approximately 150 frames of varying difficulties and lengths.

At the same time the program was being developed, another team was designing pre- and posttests. The pretest items attempted to assess the students' prerequisite knowledge. The prerequisite knowledge most usually associated with electricity is that of magnetism and atomic theory. Items were written and given to the teachers who selected 34 as most representative. The pretest was administered to all the students prior to being given the program.

The posttest was designed independently around eight typical experiments. Each experiment was accompanied by a different number and type of question. The questions were judged as best fitting into three categories. As is most often the case, the items did not fit neatly and some doubt can be raised as to the appropriation of the classification. (See Appendix A). The final form included 14 items purportedly testing knowledge, 10 items involving the recognition of a principle, and 10 items asking for the solution of a new problem. Four test forms, identical with the four program modes, concrete experiments, silent motion picture demonstration, still picture demonstration, and wholly symbolic were developed to cover the experiments. The questions themselves were in symbolic form.

It was initially planned to randomize students within levels to the 16 (four program and four test forms) treatments, but the extraordinary student movement between rooms was considered administratively unwise. The alternate solution to randomly assign classes thus introducing group error and losing within student error estimation. Sixteen heterogenously group classes, of approximately 28 students each, were then randomly assigned to a single program-test form combination. The four "adjusted" classes that remained were each given one of the program forms and the symbolic form of the test. "Adjusted" classes contained students who had general learning disabilities.

V. Results

The class means for the total and subtests are presented in Tables 2 and 3. Little differences are readily apparent. The total and subtest means for the major program and test groups are given in Tables 4, 5, and 6. No differences were apparent to support any of the three hypotheses. The variance analyses in Tables 7, 8, 9, and 10 bear this out. The only means which approached the direction of any one of the hypotheses were those of the groups taking the different program forms. The means varied in the predicted manner, from concrete to abstract, but not enough to reach the .05 level of significance.

Table 2

Criterion Test Total Means for the Classes Arranged According to Program/Test Combination.

N	Program/Test Combination	Mean	N	Program/Test Combination	Mean
25	EXP/EXP*	16.44	25	SP/EXP	16.00
25	EXP/MP	16.40	29	SP/MP	17.83
26	EXP/SP	18.08	25	SP/SP	17.12
26	EXP/SYM	17.38	26	SP/SYM	15.62
26	MP/EXP	16.38	23	SYM/EXP	14.87
26	MP/MP	17.12	25	SYM/MP	18.60
22	MP/SP	15.77	23	SYM/SP	14.48
23	MP/SYM	17.57	26	SYM/SYM	15.65

* EXP=Experiments SP=Still Picture
MP=Motion Picture SYM=Symbolic.

Table 3

Criterion Subtest Means for the Classes according to Program/Test Combination.

N	PROGRAM/TEST COMBINATION	ITEM TYPES: Program Knowledge	Principles	Problem Solving
25	EXP/EXP*	7.0	4.6	4.84
25	EXP/MP	7.04	4.44	4.92
26	EXP/SP	7.85	4.73	5.50
26	EXP/SYM	7.39	4.65	5.35
26	MP/EXP	7.0	4.35	5.04
26	MP/MP	7.19	4.88	5.04
22	MP/SP	7.05	3.86	4.86
23	MP/SYM	8.13	4.61	4.83
25	SP/EXP	6.80	4.36	4.84
29	SP/MP	7.90	4.79	5.14
25	SP/SP	7.28	4.64	5.20
26	SP/SYM	6.77	4.19	4.65
23	SYM/EXP	6.0	4.04	4.83
25	SYM/MP	7.92	5.08	5.60
23	SYM/SP	6.00	3.91	4.57
26	SYM/SYM	6.58	4.35	4.73

* EXP=Experiments SP=Still Picture
MP=Motion Picture SYM=Symbolic

Table 4

Criterion Test Total Group Means Classified According to the Program and Test Form.

N	Program Form	Mean	N	Test Form	Mean
102	EXP *	17.07	99	EXP	15.92
97	MP	16.71	105	MP	17.49
105	SP	16.64	96	SP	16.36
97	SYM	15.90	101	SYM	16.55

* EXP=Experiments SP=Still Picture
MP=Motion Picture SYM=Symbolic

Table 5

Subtest Group Means Classified According to Program Form

N	PROGRAM FORM	ITEM TYPES		
		Program Knowledge	Principles	Problem Solving
102	EXP*	7.32	4.61	5.16
97	MP	7.33	4.44	4.95
105	SP	7.31	4.50	4.96
97	SYM	6.65	4.36	4.94

* EXP=Experiments
MP=Motion Picture
SP=Still Picture
SYM=Symbolic

Table 6

Subtest Group Means Classified According to Test Form

N	TEST FORM	ITEM TYPES		
		Program Knowledge	Principles	Problem Solving
99	EXP*	6.72	4.34	4.89
105	MP	7.52	4.80	5.17
96	SP	7.07	4.31	5.05
101	SYM	7.19	4.45	4.89

* EXP=Experiments
MP=Motion Picture
SP=Still Picture
SYM=Symbolic

Table 7

Variance Analysis of Total Criterion Test Scores

Source of Variation	Sum of Squares	d.f.	Mean Square	F
Program Form	2.22	3	.74	.52
Test Form	4.52	3	1.51	1.06
Residual	12.87	9	1.43	

Table 8

Variance Analysis of the Knowledge Subtest Scores

Source of Variation	Sum of Squares	d.f.	Mean Square	F
Program Form	1.37	3	.456	1.267
Test Form	1.35	3	.45	1.25
Residual	3.25	9	.36	

Table 9

Variance Analysis of the Principle Recognition Subtest Scores

Source of Variation	Sum of Squares	d.f.	Mean Square	F
Program Form	.53	3	.177	1.40
Test Form	.14	3	.047	.37
Residual	1.13	9	.126	

Table 10

Variance Analysis of the Problem-Solving Subtest Scores

Source of Variation	Sum of Squares	d.f.	Mean Square	F
Program Form	.22	3	.07	.66
Test Form	.13	3	.045	.42
Residual	.96	9	.106	

A separate multiple regression analysis was computed to focus upon the amount of criterion total score variance predicted by the treatments, the pretest, and stanine scores from the linguistic and quantitative sections of the California Test of Mental Maturity. The zero-order correlations on an N of 281 are reported in table 11. The multiple correlation coefficient between the five predictor variables and the criterion was .50. The pretest accounted for 19% of the predicted variance while the others were negligible (see table 12).

Table 11

Zero-Order Correlation Matrix Including
Predictor Variables and Criterion Test Total Score

	Program Form	Test Form	Pre-Test	Linguistic Stanine	Quantitative Stanine	Criterion Total
Program Form	1.00	.01	-.06	-.07	.04	-.10
Test Form		1.00	.17	.22	.18	.12
Pre-Test			1.00	.56	.43	.45
Linguistic Stanine				1.00	.50	.40
Quantitative Stanine					1.00	.31
Criterion Total						1.00

Table 12

Proportion of Criterion Total Test Variance Attributable to the Predictor Variables

Predictor Variables	Variance Proportion
Program Form	.01
Test Form	.01
Pretest	.19
Linguistic Aptitude	.02
Quantitative Aptitude	.01

The initial zero-order linguistic and quantitative correlations with the criterion test were accounted for the pretest in the multiple correlation. There seemed to be no apparent relation between the scholastic abilities and performance due to working with any of the program forms.

The "adjusted" classes, those who have learning problems, did not seem to benefit from the more concrete experiences. (see table 13). Their problems seem to be much greater than any change in modality can solve.

Table 13

Criterion Test Total Means for the Adjusted Classes

Type of Program	Mean
Experiment	7.5
Motion Picture	7.2
Still Picture	9.8
Symbolic	5.0

One more level of analysis remained, that of success on individual items, as no differences could be found in the overall and subtest scores. A series of item frequency plots for each modality, when juxtaposed, demonstrated little or no variation. The modality changes had no differential effect in terms of item error counts. (See Appendix B).

VI. Discussion

A. Overview

The lack of differences suggest one or a combination of the following explanations:

1) Seventh grade students are capable of dealing with abstractions and do not need the more concrete form; 2) the experiments were already within their direct experience so they did not need to return to these experiences to comprehend; 3) the concepts and principles of electricity are at such a level of abstraction that partial understanding is the best one can expect at this age (note: some of the teachers professed difficulty); 4) the use of words both to direct the student through the experiments and as expository material between experiments may have negated any possible gain from the more concrete representations; 5) the low reading abilities, known to exist with these students, might have hindered comprehension using all representational forms. It seems that given the right set of conditions, developmentally apt, experienced students who can read that information transmitted in the symbolic form such as programed instruction may be as effective as more concrete experiences, plus being less expensive and less time-consuming.

Summarizing, the generality of the "experience" principle is questioned. The principle should probably be replaced by a set of conditional statements that delineate such characteristics as age of the learner, abstraction of the task, and probability of the example of being in the learner's experience.

B. Possible Explanations

First, it is possible that seventh grade students are developmentally able to deal with words without recourse to pictures or actions and things. Their language-experience repertoire and cognitive functioning may be mature enough to enable them to imagine from words what they may not have actually experienced. The "qualitatively new capacity" that emerges, as Ausubel describes it, may have already emerged. More definitive research obviously needs to be done to provide further clues to this developmental question.

Second, the performance of the students can be explained by the inference that the experiments chosen were already within the student's repertoire. This reasoning is in line with Ausubel's initial logic that once meaning is established there is no need to return to the concrete form. In searching for inexpensive, easily replicated, durable examples of the various principles, the research team decided upon situations which were probably common to most of the students. And yet like most instructional decisions this one involves certain utility considerations. The possibility of a student not having contact with a certain experience may be minimal, but when the materials are accessible and easily manipulated it probably is worth the effort of having them available rather than just, as in this case, read about them. However, any "gain in understanding" for most of the students is, from the results of this study, doubtful.

Not finding differences in the transition from program form to test form further validates this explication. If the students were able to comprehend equally as well from the most abstract, symbolic representation, then it follows that there would be no difficulty moving among any of the more concrete forms.

Third, the difficulty the teachers had in attempting to develop the instructional sequence and their admission of being conceptually vague, leaves some doubt concerning the "level of understanding" one can expect from seventh graders. Concepts such as electricity, which have many theoretical explanations due to the inability to observe them directly, are undoubtedly destined to varying comprehension. What these "levels of understanding" might be and how to predict relative performance among them is little more than a vague conceptualization itself. The abstractness of the task may override the modality decision, that is, a concept that has no direct referent may call for a more abstract rather than concrete representation. Or perhaps its non-referential nature is so limiting that comprehension is just not reasonable for many students.

Another factor which undoubtedly had some bearing on the outcomes was the dependence upon the written symbol. Although the six experiments were in other forms, the basic story line of the program remained in the symbolic mode. This dependence upon the abstract word form may have diminshed any possible gains from the more concrete supplementary information.

A complementary and perhaps even greater problem than the dependence upon words was that of reading disability. Reading difficulties precede and can therefore mask what were intended to be treatment deficits--that of not comprehending the more abstract symbolic mode. It may often be that in the case of the poorer student that he cannot recognize, let alone comprehend, the word "insulator," for example. Presentation of the concrete example means little when the associated symbolic explanation cannot be read. If the basic sequence had been put on tape and presented audially, some of these problems may have been overcome. Even then, it becomes a trade-off; listening comprehension disabilities for those in reading.

C. Secondary Questions

That there was no effect of the change of representative mode upon higher levels of cognitive functioning (principle recognition and problem solving) might have been expected. The modality decision logically relates to the acquisition phase of learning, not to any of the subsequent generalization skills which seem to be called for in principle recognition and problem solving. The teaching of these skills is usually thought of as being dependent upon other instructional variables, such as example sequence and variety, interrogational strategy, and most important, practice.

The question concerning the relationship of the varying student linguistic and quantitative aptitudes and the ability to acquire the content using different forms also appears to remain unanswered due to the choice of experiments. There was no opportunity, without an effect due to the program forms, for those who were more apt to benefit from their aptness.

D. Possible Difficulties in Task Guidance

A further problem regarding the interaction of student and material concerns the amount of task guidance given. For example, the program: 1) asked the question, 2) told the student what to look for, and 3) told him when he had found it. Is this restrictive strategy really what is meant by 'teaching by concrete referent': Or is it as Duckworth (1964), summarizing Piaget, demands that "Good pedagogy must involve presenting the child with situations in which he himself experiments in the broadest sense of that term trying out things to see what happens, manipulating things, manipulating symbols, posing questions and seeking his own answers, reconciling what he finds at one time with what he finds at another, and comparing his findings with those of other children." (p. 173). The author can remember vividly how one youngster wanted to keep fiddling with each experiment only to have his curiosity stunted by constant reprimands and being told to get back to his seat and finish the program!

The amount of task guidance in this situation, as it does in the more general issue of discovery-exposition, involves utility considerations. Just how much guidance do we give to accomplish the task in the most efficient way for a group of widely heterogeneous students?

Other writers, Smedslund (1964) and Charlesworth (1964), have emphasized that the elements of contradition and surprise should be incorporated within the direct contact of student and material. Perhaps the major form of guidance given the student should be some definite deviation from the expected within each laboratory or classroom experiment-example. Charlesworth states, "Exposure to the unexpected for us is accommodation (rather than just assimilation) and thus increases the chances of subsequent modifications of existing cognitive structures. It is these modification that most likely increase the latitude of the subject's adaptive capacities." (p. 215). In other words, 'passive' perception of a situation without trial, feedback, and adjustment to the task may be insufficient to bring about what educators term 'greater understanding.' And yet Bruner found that younger children can be confused by the apparent contradiction of "more" water in the tall, thin vessel where they could deal with it intellectually without the image!

E. Developmental Difficulties

The inability to revise the program by student test rather than teacher judgment was a major limitation as Silberman and Carter (1966) point out. They found significant differences between crucial variables using revised programs where there were none with the program not revised. And yet if the content is hierarchically structured, and the major logistic strategy is group pacing, it becomes impossible to carry out an individual survey of program items. The students are not "ready" in the sense of acquisition of prerequisite skills until the very week the program is to be administered! The chapters of most science tests are based upon this hierarchical notion, that the prerequisite concepts precede the more complicated, i.e., magnetism before electricity. As such the "true" target sample can only be tested at one point during the year. Like a passing bus, you can only catch it on time or you have to wait for another--in our case, another school year.

The other developmental problems are also worthy of repetition. First, the issue of exposition-discovery was raised with the grade teachers favoring exposition, and the college teachers, discovery. Second, each participant offered a unique sequence to teach the same unit. And finally, there was the admission of "really not understanding electricity" by some of the teachers. These developmental problems are not usually noted in the published report of study. And yet they are many times considerably more important than the variable or variables under scrutiny.

F. General Conclusion

Vygotsky (1939) stated some time ago that, "The development of a scientific concept usually begins with its verbal definition and its use in non-spontaneous operations--with working with the concept itself." (p. 108).

Physical science concepts and principles are not, however, limited by representation by non-spontaneous operations, but quite to the contrary can usually be explained by reference to common spontaneous operations. It seems that a verbal program, which begins by stating the verbal definition and then relates descriptions of these spontaneous operations within the students' experience-language repertoire, can be as effective as one which employs more concrete representations. The modality decision then becomes a question of the teacher's facility with the subject matter and knowledge of his students, that is, his being able to generate examples and non-examples which are ordinary enough to be within the students' repertoire.

The problem of transition between modalities, in this case from program to test, also appears to be solved when supposedly experienced examples are chosen. These seventh grade students could move from one form to the other without apparent difficulty. It still seems reasonable that non-experienced examples of concepts and principles, given in the more abstract form, would hinder both acquisition and transition of content. But that needs to be tested. And yet, how many and which of the concept and principles of science do not have examples which are the common, spontaneous experiences of students?

Summarizing, the generality of the "experience" principle is questioned. The principle should probably be replaced by a set of conditional statements that delineate such characteristics as age of the learner, abstraction of the task, and probability of the example of being in the learner's experience.

APPENDIX A

Criterion Test

QUESTION #1

Suppose you did the following: Pick up a piece of paper and place it over a metal bar. Now pick up a shaker of iron filings and sprinkle the filings all over the paper. When you sprinkle the iron filings over this metal bar, they do not make a pattern.

(p) a. Why doesn't this metal bar make patterns?
(k) b. What were these iron filing patterns called in your program?
(k) c. Draw the pattern they would usually take.
(k) d. Draw the pattern the iron filings would make if you sprinkled them on a coil of wire which had electricity running through it.

(k) = knowledge retrieval
(p) = principle recognition
(ps) = problem-solving

QUESTION #2

Suppose you did the following:
Rub the black plastic rod with the fur. Now pick up the piece of glass and hold it between the little ball and the tip of the nail. Bring the plastic rod near the hitting end of the nail. When you brought the rod near the nail, the pith ball should not have moved.

Do the same thing but use the piece of cork in place of the glass. Do it again with a piece of rubber.

With the glass, cork, and rubber between the nail and the little ball, the little ball does not move.

(k) a. What kind of material is the cork, glass, and rubber?
(ps) b. What would you do to attract the little ball?
(p) c. Why?
(k) d. When electrons pass along a conductor they are called a ______________ of electricity.
(k) e. When the electrons collected on the tip of the black rod they formed ________________ electricity.

QUESTION #3

Suppose you did the following:
Pick up the copper plate and hook one end of the wire to it and push it into the lemon. Attach the other end of the same wire to the galvanometer. Hook the other wire onto the other copper plate and push it into the lemon but make sure they do not touch. Attach that wire to the other part of the galvanometer.

When you attached both wires to the galvanometer, nothing happened to the needle.

(p) a. Why wasn't any electricity produced?
(ps) b. What would you do to make the cell work?
(k) c. Describe how it should really work.

QUESTION #4

Suppose you did the following:
Fold a sheet of newspaper and put the fold over the sharp edge of your ruler. Note how the paper hangs. Now lay the strip of paper out on the table and put your fingers on the very end of it. Scrape the ruler along the strip of paper three or four times. Now slip your ruler under the middle of the newspaper and hold it up again like you did before.

When you hold it up this time, the ends of the newspaper spread apart.

(k) a. When you scraped the strip of paper, what would the scraping be called?
(ps) b. What would the scraping do to the ends of the paper?
(p) c. Why do the ends of the paper spread apart when they have been rubbed?
(ps) d. If it were possible to put extra electrons on one end of the newspaper and take away electrons from the other end of the paper what would they do?
(p) e. Why?

QUESTION #5

Suppose you did the following:
Pick up the piece of wood with the coil of wire wrapped around it. Attach one end of the wire to the center of the dry cell and the other wire to the edge. Now try to pick up the paper clip with the wood.

- (k) a. Is the piece of wood a conductor or insulator?
- (p) b. Why won't the piece of wood pick up the paper clip?
- (ps) c. Would increasing the number of coils on the wire make the piece of wood pick up the paper clip?
- (ps) d. Would increasing the amount of electricity make the piece of wood pick up the paper clip?
- (ps) e. Is there another way to make it work? What is it?
- (k) f. What would you be able to call it if you made it work?

QUESTION #6

Suppose you did the following:
Pick up the comb and comb the hair of the doll wig several times. Now hold the comb over the bits of paper on the table. Your comb picked up the pieces of paper.

- (k) a. What does running the comb through the hair do to the comb?
- (k) b. If the comb attracts or picks up the paper, the paper must have a ______________ charge than that on the comb.
- (p) c. Would you be more likely to get a good static charge on the comb on a cold, dry winter morning or a hot, humid summer afternoon?
- (p) d. The more you comb the wig, the more the strands of hair on the wig tend to stick out in the air even when the comb is taken away. Can you give an explanation for this?
- (ps) e. You may have heard that a person's hair will stand straight up when he is scared. Can you explain this with the information you have learned about electricity?

QUESTION #7

Suppose you did the following:
Pick up the zinc and the copper and put them into the water in the tank. Connect the wires to the galvanometer.

(k) a. What does it mean when the needle does not move?
(p) b. Why didn't the set-up work as it is?
(ps) c. Knowing you have two different metal conductors, what is missing that would make the set-up produce electricity?

QUESTION #8

Suppose you did the following:
Pick up the flashlight. Put one battery in with the central terminal towards the open top. Put the second one into the flashlight with the central terminal toward the bottom so the two center terminals are touching. Screw on the top and push the switch.

(p) a. Why doesn't the flashlight work?
(ps) b. How would you change it to make it work?
(k) c. Describe how a flashlight battery produces electricity.

APPENDIX B

Item Frequency Counts For Each Of The Criterion Test Items Within Each Program/Test Combination Class

	1b	1c	1d	2a	2d	2e	3c	4a	5a	5f	6a	6b	7a	8c
Exp Exp	10	11	24	16	10	5	14	15	5	11	5	22	7	20
Exp Mp	10	10	22	12	8	4	17	17	4	16	8	21	6	19
Exp Sp	13	13	20	12	5	3	16	11	4	15	5	17	8	18
Exp Sym	13	13	24	15	7	0	15	14	4	15	6	22	5	19
Mp Exp	7	8	26	9	9	8	20	16	7	10	8	22	10	22
Mp Mp	9	13	26	15	6	2	17	16	5	12	9	19	12	16
Mp Sp	11	12	19	8	6	4	16	10	1	10	11	18	10	17
Mp Sym	10	9	17	7	2	2	14	10	2	12	6	15	11	18
Sp Exp	10	16	22	8	9	9	14	8	4	14	9	21	16	20
Sp Mp	11	11	27	7	6	5	18	14	1	14	7	26	9	21
Sp Sp	14	16	24	13	7	3	16	17	3	8	4	22	8	13
Sp Sym	10	17	24	15	4	3	18	13	4	12	11	21	12	24
Sym Exp	5	12	21	12	16	11	17	15	4	7	10	21	12	21
Sym Mp	11	10	25	7	8	2	17	15	5	10	5	16	5	16
Sym Sp	9	13	23	13	9	3	20	16	6	7	9	21	15	20
Sym Sym	10	11	26	15	10	5	19	13	5	12	12	22	12	21

Item Frequencies (cont.)

	1a	2c	3a	4c	4e	5b	6c	6d	7b	8a
Exp Exp	9	14	12	16	14	7	11	23	17	12
Exp Mp	4	14	15	17	16	8	9	21	23	12
Exp Sp	10	9	13	17	18	8	16	23	15	8
Exp Sym	11	16	14	18	13	10	14	20	16	7
Mp Exp	3	15	18	20	15	11	12	24	20	9
Mp Mp	6	14	17	18	13	6	12	17	18	12
Mp Sp	6	11	15	19	20	9	16	16	15	8
Mp Sym	4	6	12	16	16	8	16	18	16	12
Sp Exp	4	19	9	17	17	5	15	20	22	13
Sp Mp	10	9	15	14	17	10	19	25	23	9
Sp Sp	8	7	14	19	17	6	16	18	21	8
Sp Sym	6	15	16	18	17	6	16	24	21	12
Sym Exp	0	17	5	21	19	11	12	22	20	10
Sym Mp	8	13	16	13	14	5	13	19	14	8
Sym Sp	3	13	18	16	16	13	12	18	18	13
Sym Sym	5	15	18	19	14	9	15	20	18	14

Item Frequencies (cont.)

	2b	3b	4b	4d	5c	5d	5e	6e	7c	8b
Exp Exp	13	13	16	13	5	6	12	25	18	8
Exp Mp	14	18	14	7	3	4	12	24	21	10
Exp Sp	9	12	17	8	1	4	13	25	17	11
Exp Sym	14	15	16	8	2	5	14	25	13	9
Mp Exp	14	18	14	13	3	5	11	26	19	6
Mp Mp	15	17	13	9	4	7	11	26	16	11
Mp Sp	9	14	13	12	5	6	14	22	12	6
Mp Sym	8	13	14	12	4	4	16	23	17	8
Sp Exp	16	9	11	14	10	3	8	24	21	13
Sp Mp	7	16	15	9	5	8	19	27	23	12
Sp Sp	7	14	15	11	4	6	8	25	20	10
Sp Sym	9	17	15	16	7	4	14	26	20	11
Sym Exp	13	6	18	13	4	6	7	23	20	9
Sym Mp	11	15	16	7	5	5	8	22	14	7
Sym Sp	14	18	14	10	3	5	10	23	16	12
Sym Sym	12	18	13	12	5	9	14	26	15	13

BIBLIOGRAPHY

1. Allen, William. "Audio-Visual Communication," Encyclopedia of Educational Research, 1962.

2. Aronson, A. E. and Irwin, J. V. Television Teaching. Conventional Lecture Versus Highly Visualized Film Presentation, Research Bulletin No. 11, Madison, Wis.: University of Wisconsin Television Laboratory, Dec., 1958.

3. Ausubel, David P. The Psychology of Meaningful Verbal Learning, (New York: Grune and Stratton, Inc., 1963), pp. 111-135.

4. Ausubel, David P. "The Transition from Concrete to Abstract Cognitive Functioning," Journal of Research in Science Teaching, John Wiley & Sons, 1964, Vol. 2.

5. Bruner, Jerome. Toward a Theory of Instruction, Harvard Press, Cambridge, Mass., 1966.

6. Charlesworth, William. "Development and Assessment of Cognitive Structures," Journal of Research in Science Teaching, John Wiley & Sons, 1964, Vol. 2, Issue 3, p. 214-220.

7. Cunningham, Harry A. "Lecture Demonstration Versus Individual Laboratory Method in Science Teaching--A Summary," Science Education, 1946, Vol. 30, pp. 70-82.

8. Dale, Edgar. Audio-Visual Methods In Teaching, (New York: The Dryden Press, Inc., 1946), pp. 37-52.

9. Duckworth, Eleanor. "Piaget Rediscovered," Journal of Research in Science Teaching, John Wiley & Sons, 1964, Vol. 2, Issue 3, pp. 172-176.

10. Filep, Robert, "Is a Picture in a Frame Worth a Thousand Words?", Programed Instruction, Vol. IV, No. 8, 1965, pp. 3-4.

11. Gagne, Robert. The Conditions of Teaching, Holt, Rinehart & Winston, 1965.

12. Gropper, George L. Studies In Televised Instruction the Role of Visuals in Verbal Learning, Title VII, Project No. 637, National Defense Educ. Act of 1958, Grant No. 7-36-120.01.

13. Karplus, Robert. "The Science Curriculum-One Approach," Elementary Scholastic Journal, 1962, Vol. 62, pp. 243-252.

14. Mechner, Francis. "One View of Programmed Instruction," Current Science Teacher's Edition, Vol. XLIX, No. 32, May 11-15, 1964.

15. Piaget, Jean and Inhelder, Barbel. The Growth of Logical Thinking from Childhood to Adolescence, New York: Basic Books, 1958.

16. Rulong, Philip J., The Sound Motion Picture in Science Teaching, Harvard University, 1933.

17. Smedslund, Jan. "Internal Necessity and Contradiction in Children's Thinking," Journal of Research in Science Teaching, John Wiley & Sons, 1964, Vol. 2, Issue 3, pp. 220-222.

18. Smith, M. Daniel. "An Exploration of Non-Wordal Programming in Mathematics and Science," Research Grants and Contracts Programmed Learning and Self-Instructional Media, Title VII, No. 977, U. S. Dept. of Health, Education, and Welfare, Feb., 1963, pp. 30-31.

19. Vernon, P. E. "An Experiment on the Value of the Film and Film-Strip in the Instruction of Adults," British Journal of Educational Psychology, 1946, Vol. 16, pp. 149-62.