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ABSTRACT

In the study, one of each of pairs of average and high ability eighth-grade classes was designated, by random means, as the experimental class. Students in the experimental classes viewed projected 2 x 2 colored slides which represented sequences of the same laboratory activities as those performed by the manipulative group. All other instructional procedures were constant for both groups. No significant differences resulted from the employment of either method in the laboratory activities in the Introductory Physical Science (IPS) course, when judged in terms of student progress as reflected in test scores related to: (1) critical thinking skills, (2) understanding of science, (3) academic achievement of knowledge and concepts presented in IPS, and (4) development and expression of interest in science. The manipulative method was significantly superior to the nonmanipulative method for the development of selected laboratory skills. Academic achievement and performance of the students in the nonmanipulative group did not support the view expressed by the teachers that the manipulatory method of laboratory instruction is necessary for motivation and satisfactory learning of science as defined by the IPS course. The IPS course did not appear to stimulate student interest in science after one semester of instruction. (Author/CP)

THE RELATIVE EFFECTIVENESS OF TWO METHODS OF UTILIZING LABORATORY-TYPE ACTIVITIES IN TEACHING INTRODUCTORY PHYSICAL SCIENCE

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Technical Report No. 65

THE RELATIVE EFFECTIVENESS OF TWO METHODS OF UTILIZING LABORATORY-TYPE ACTIVITIES IN TEACHING INTRODUCTORY PHYSICAL SCIENCE

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Report from the Science Concept Learning Project
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PREFACE

Contributing to an understanding of cognitive learning by children and youth—and improving related educational practices—is the goal of the Wisconsin R & D Center. Activities of the Center stem from three major research and development programs, one of which, Processes and Programs of Instruction, is directed toward the development of instructional programs based on research on teaching and learning and on the evaluation of concepts in subject fields. The staff of the science project, initiated in the first year of the Center, has developed and tested instructional programs dealing with major conceptual schemes in science to determine the level of understanding children of varying experience and ability can attain.

Laboratory experiences have been considered necessary to science instruction, not only for learning of specific skills but also for developing the ability to formulate conclusions based on observations and data and for learning the nature of scientific activity. The exploratory study reported in this Technical Report was an attempt to compare the effectiveness of nonmanipulative laboratory experiences with the traditional manipulative type laboratory experiences in terms of commonly accepted objectives. Eighth-grade classes using nonmanipulative laboratory exercises performed as well on tests of critical thinking and understanding of and achievement in science as similar classes who carried out the experiments in a traditional manner. It was suggested that laboratory experiences seem necessary for some manipulative skills; however, it does not seem that the traditional laboratory activities are as effective as believed.

Herbert J. Klausmeier
Director

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ABSTRACT

This study was concerned with determining the relative effectiveness of a direct manipulative and an indirect nonmanipulative method of utilizing laboratory-type activities in teaching the course Introductory Physical Science (IPS). The hypothesis to be tested was that there is no significant difference due to method in the (1) attainment of critical thinking skills, (2) understanding of science, (3) development of specified laboratory skills, (4) attainment of knowledge and concepts presented in IPS, and (5) expression of interest in science.

The design, which allowed for the testing of each main effect as well as two- and three-factor interactions, was a 2 x 2 x 2 factorial, with the factors being treatment, IQ, and sex.

One of each of the two pairs of average and high ability eighth-grade classes was designated by random means as the experimental class, and the other as the control class. The students in the experimental classes viewed projected 2 x 2 colored slides which represented sequences of the same laboratory activities as those performed by the manipulative group. The group that did not manipulate equipment was designated as the nonmanipulative group. All other instructional procedures were constant for both groups.

Five instruments were administered as pretests in early September 1967, and as posttest in late January 1968; the Kuhlmann-Anderson Test, Form G, was administered at the beginning of the fall term to determine the IQ of the students.

Conclusions

1. No. significant differences resulted from the employment of the manipulative or nonmanipulative methods in the laboratory activities provided in the IPS course when judged in terms of student progress as reflected in test scores related to: (a) critical thinking skills, (b) understanding of science, (c) academic achievement of knowledge and concepts presented in IPS, and (d) the development and expression of interest in science.
2. The manipulative method was significantly superior to the nonmanipulative method for the development of selected laboratory skills.
3. Students in both groups with high IQ's earned higher test scores than students with low IQ's.
4. Achievement using the IPS course is not related to sex.
5. There were no significant interactions.
6. The academic achievement and performance of the students in the nonmanipulative group did not support the view expressed by the teachers that the manipulatory method of laboratory instruction is necessary for motivation and satisfactory learning of science as defined by the IPS course.
7. The IPS course does not appear to stimulate student interest in science after one semester of instruction.

I
THE PROBLEM

INTRODUCTION

Many investigations of learning utilizing different methods of instruction in elementary and secondary school science have been completed during the past several decades. Perhaps one of the most researched topics related to the teaching of science in the secondary school has been the relative effectiveness of the laboratory as an instructional tool in the achievement of the desired objectives. Curtis (1939) indicated that more research was devoted to this than to any other problem dealing with the teaching of science. This was particularly true in the period from 1900 to 1935 when the secondary school population doubled each decade and the growth of the schools resulted in heavy public financial burdens. The science laboratory with its high cost of material, furniture, apparatus and equipment was thus open to criticism. The suggested alternative to the laboratory was the use of classroom demonstrations. Extensive reviews of the literature by Cunningham (1946), Curtis (1926, 1931, 1939) and Reidel (1927) revealed that the research suggested that the lecture-demonstration method was as effective as the individual laboratory method. However, many of the research studies were not without criticism. Cunningham (1946) stated:

> No absolute decision on the general problem for all cases and for all time can ever be made. It should be assumed that we are going to continue using several methods in the teaching of science and that much more analytical work will be necessary to decide the circumstances under which, and the kind of experiments and exercises with which, each method will be found successful.

It is worth noting that the Fifty-ninth Yearbook of the National Society for Study of Education (NSSE), Rethinking Science Education (1960), did not include debate of the problem of the laboratory versus demonstrations in secondary science education. It was stated that:

> every classroom where science is taught should be a place for experimentation. The laboratory should create opportunities wherein the student predicts events of circumstances and then designs experiments to test the accuracy of his predictions.

Today most science educators agree that the laboratory has important functions in science instruction and recognize the influence of the science curriculum studies of the sixties with their emphasis on laboratory experiences. Hurd (1964), in an attempt to formulate a theory of science education, stated that the laboratory is central to the teaching of science. Murdock (1959) pointed out:

> Most of us feel that a science course without a laboratory phase is not wortny of the name science. The very nature of science explains this devotion to the laboratory. Interwoven in the history of science is the experiment, so it is only natural that the opportunity for experiment be part of the process of learning a science. If a person is to understand fully and continue in science, he must be familiar with the methods and techniques of the scientific laboratory. You cannot effectively teach a mechanic by books alone; by the same token, a scientist must be able to manipulate his hands as well as his mind.

The Joint Commission on the Education of Teachers of Science and Mathematics expressed the view that "laboratory work should form the core of instructional programs. .... It should have for the student the same primary value it offers the scientist as a method of finding answers to fundamental questions [1960]."

Given that laboratory experiences comprise an essential ingredient of a science curriculum, what specific contributions can be attributed to their use? Richardson (1957) suggested that laboratory experiences should (1) provide a source of problems for students to solve, (2) provide for the solution of problems, (3) promote understanding of the scientist's role, (4) provide illustrations of phenomena, (5) teach principles and concepts, and (6) contribute to the development of skills, habits and attitudes. An analysis by Pella (1961) of high school textbooks and laboratory workbooks as well as interviews with 140 teachers of science revealed the following contributions of laboratory activities:

1. A means of securing information
2. A means of determining cause and effect relationships
3. A means of verifying certain factors or phenomena
4. A means of applying what is known
5. A means of developing skill
6. A means of providing drill
7. A means of helping pupils learn to use scientific methods of solving problems
8. A means of carrying on individual research.

Stollberg (1953) pointed out that, as a result of laboratory experiences in science, students should

1. increase their ability to do critical thinking
2. increase their powers of observation
3. develop keenness of initiative
4. gain a deeper insight into the work of the scientist and the role of science and the scientist
5. acquire improved understanding of basic concepts, principles and facts of science
6. increase their proficiency in generally useful skills and useful skills directly related to the science laboratory
7. develop an interest in and a curiosity about principles and processes related to science

Glass (1967) contended that through the performance of challenging laboratory experiences students can become familiar with processes of science such as measurement, data collection, prediction, hypothesis formation, analysis and interpretation. Students then can learn to recognize the spirit of science and appreciate its methods.

The interest in this study is with several predicted outcomes of laboratory experiences: critical thinking, understanding of products and processes of science, laboratory skills, knowledge of certain concepts and principles, and interest in science.

As a result of investigations by Mason (1963), Rickert (1967), George (1965), Yager and Wick (1966) and Kastrinos (1963), one can conclude that critical thinking can be taught. Dressel (1954), stated that work in the laboratory creates the opportunity wherein the student can obtain firsthand acquaintance with the appropriate activities that encourage critical thinking.

Glaser (1941), defined critical thinking as:

> (1) an attitude of being disposed to consider in a thoughtful way the problems and subjects that come within the range of one's experiences, (2) knowledge of the methods of logical inquiry and reasoning, and (3) some skill in applying those methods. Critical thinking calls for a persistent effort to examine any belief or supposed form of knowledge in the light of the evidence that supports it, and the further conclusions to which it tends. It also generally requires ability to recognize problems, to find workable means for meeting those problems, to gather and marshal pertinent information, to recognize unstated assumptions and values, to comprehend and use language with accuracy, clarity, and discrimination; to interpret data, to appraise evidence and evaluate arguments, to recognize the existence (or non-existence) of logical relationships between propositions, to draw warranted conclusions and generalizations, to put to test the conclusions and generalizations at which one arrives, to reconstruct one's patterns of beliefs on the basis of wider experience, and to render accurate judgments about specific things and qualities in everyday life.

The NSSE in its Fifty-ninth Yearbook (1960) listed as one of the aims of better science teaching "to develop an understanding and appreciation of science and scientists which may last usefully through life." A review of the studies reported by Crumb (1965), Trent (1965), Jerkins (1968), Cooley and Klopfer (1963a, 1963b, 1964), and McCann (1968), supports the conclusion that it is possible to measure a student's "understanding of science and scientists." Crumb (1965), in discussing results of a study, concluded that test scores on "The Test on Understanding Science" of students using a laboratory-centered approach were significantly higher than the test scores of students using a text-centered approach.

Wynn and Bledsoe (1967), investigated the gain and loss of scientific interest during high school and concluded "that the extreme emphasis which has been placed upon science and science education during recent years has not resulted in greater interest in science." A review of the literature by Wynn and Bledsoe related to the development of science interest revealed that one of the factors most often credited for the stimulation of interest in science was science courses and laboratory experiences. Norton (1963), suggested that a well organized junior high school science and laboratory program can promote and encourage an interest in science.

Mathewson (1967), in discussing the functions of student laboratories, stated, "We should not slight the teaching of skills in our concern for getting students to think. Science is one of the last refuges of true craftmanship; manipulative skill and imagination should be rewarded."

In an evaluation of science laboratory instruction Jeffrey (1967), suggested that the manipulative competence of the student is an important consideration. Jeffrey stated that:

> A manifest deficiency of high school graduates is a lack of competence in such elementary laboratory operations as pouring liquids, filtering solids, using a balance, adjusting a burner, using a pipet, using a buret, etc.

Nedelsky (1965), also listed the teaching of specific laboratory skills and techniques as a common objective. He suggested that performance tests should be given to measure directly the attainment of laboratory skills and techniques.

Historically, there have been attempts to identify and to evaluate specific selected outcomes resulting from laboratory experiences. However, Pella (1961), in an article on the laboratory and science teaching, pointed out that the results achieved in the laboratory depend upon the way the laboratory is used and the particular steps performed by the teacher or the students. He suggested that in the process of obtaining information the following common steps be given for scientific problem solving:

1. Statement of problem
2. Formulation of hypotheses
3. Developing a working plan
4. Performing the activity
5. Gathering the data
6. Formulation of conclusions

One related reference to laboratory work in science teaching from a point of view basic to the NSTA Theory Into Action is (1964):

> To achieve its greatest educational value, work in laboratory must provide opportunities for the student to interpret observations and data. ... Here [in the laboratory] meaning is given to observations and data. The data from an experiment remain inert facts until rational thinking makes something more of them. It is at this point that work in the laboratory has its greatest educational value. ... Experiments solely for the purpose of gathering data, even though the data are carefully described and summarized, represent merely a preliminary step for understanding science. To collect experimental data is not enough. The student must learn to formulate statements against theory. ...There are other factors associated with making the best use of laboratory procedures in schools. These include ...a wider use of mental experiments.

This expressed point of view implies that one of the most important values of the laboratory is the thinking a student does about the data and observations from an experiment; the collection of data contributes little to the understanding of science. In a report by the State Advisory Committee on Science Instruction in California High Schools (1965) on the role of the laboratory, it is stated, "The necessity for laboratory investigation goes beyond the need for manipulative experience." These statements and others as well as experience in teaching led to the formulation of the problem studied here.

Within the structure of many of the more recent science courses, like Introductory Physical Science, considerable emphasis is placed on the laboratory as a teaching tool to realize the desired skill and concept outcomes. The skills are the physical manipulations involved in generating and collecting data and the concepts are to be developed as a consequence of the analysis and synthesis of these data. Since manipulation of apparatus requires large amounts of time, a question related to the economy of the learner's time utilizing the laboratory method may be asked. Does the manipulative aspect of the laboratory exercise contribute to the learning?

THE PROBLEM

> To determine the relative effectiveness of two methods of utilizing laboratory-type activities in teaching the course Introductory Physical

Science (IPS), the direct manipulative approach and the indirect nonmanipulative approach.

The manipulative approach use of the laboratory is here defined to include direct pupil contact with apparatus and the nonmanipulative approach to omit the direct pupil contact with apparatus.

In pursuance of this problem the hypothesis tested was that there is no significant difference due to method in the (1) attainment of critical thinking skill, (2) understanding of science, (3) development of specified laboratory skills, (4) attainment of knowledge and concepts presented in IPS, and (5) expression of interest. Sex and IQ were investigated for main effects as well as interactions.

SIGNIFICANCE OF THE STUDY

Since the utilization of the best and most efficient known methods of instruction is a responsibility of all educators, it is obligatory that if, in the study of the use of the laboratory in a teaching procedure, it is found that students who did not manipulate equipment performed as well on selected valid test instruments as students who manipulated apparatus, there would be need to consider other approaches to the use of the laboratory in teaching science. Exercises that are mainly designed to verify, to repeat classical experiments, or to teach facts might be utilized without the direct manipulation of equipment. It is possible that laboratory exercises involving apparatus manipulation could be used for more specific purposes as individual research problems and a better understanding of and/or interest in science.

II
RELATED LITERATURE

STUDIES OF THE USE OF MOTION PICTURES

It was Averill (1915) who expressed one of the first concerns for the use and preparation of visual materials designed for teaching in the classroom. This article apparently served as the stimulus for others. Sumstine (1918), as a result of an empirical study in which he compared the achievement of pupils taught using a visual-auditory method with those taught using an auditory method, reported that audiovisual materials did contribute to learning.

Davis (1923), while discussing the teaching of general science, expressed the opinion that motion pictures could be used to set up problem-solving situations.

> We can set up a problem, give the mind facts to work with, and then by the use of these facts, solve the problem. The pupils could solve the problem from the material presented in a film. There are scores of problems that could be solved by the use of a film.

Davis suggested another use for a type of film that he called the contrast film:

> It will be possible to present all the data on both sides of any problem and let the pupils decide for themselves what the correct solution might be. ....From this array of facts, I am quite certain that pupils will not only arrive at more sane conclusions, but also their conclusions will be more permanent. The impressions created by the films will be more realistic to the pupils and the conclusions reached will be more apt to become a part of their daily life, than if the same results had been obtained by reading a textbook or listening to the teacher telling them what to do.

The apparent perception Davis held in relation to the research needs in the use of audiovisual aids in teaching is evident in the following statement:

> Many types of problems can be presented by the use of a film in a much shorter time than they can be demonstrated in the laboratory. There is a film on the telephone that presents most of the facts in less than ten minutes. It presents all of the facts and principles that are ordinarily demonstrated in the laboratory. Very little demonstration could be done in the laboratory in less than one hour. Even though we have saved time, we ought to question ourselves as to whether a pupil would gain as much by seeing the film demonstration of the telephone as he would by actually handling the apparatus and materials he uses in the laboratory. As far as I know, no one has worked out this problem. ....It would be an interesting problem to decide what value each method has.

In essence Davis is indicating the need to answer a very basic question: What distinct contributions can audiovisual materials make to the teaching of science? Although the number of research studies related to the utilization of audiovisual material in the teaching of science is limited, research activity concerned with audiovisual materials and school subjects has been noted. The outcomes formulated by Dale (1954), based on 120 "significant" studies reported in the Encyclopedia of Educational Research, are the following:

1. They supply a concrete basis for

conceptual thinking and hence reduce meaningless word-responses of students.
2. They have a high degree of interest for students.
3. They make learning more permanent.
4. They offer a reality of experience which stimulates self-activity on the part of the pupils.
5. They develop a continuity of thought; this is especially true of motion pictures.
6. They contribute to growth of meaning and hence to vocabulary development.
7. They provide experiences not easily obtained through other materials and contribute to the efficiency, depth, and variety of learning.

These seven points constitute general conclusions; however, it is necessary to consider several of the specific studies, especially in science.

The value of visual materials and techniques in science teaching was suggested in the Thirty-first Yearbook of the NSSE (1932):

> Glass slides, home-made slides, film-slides, micro-slides, opaque projection, and motion pictures all have a valuable place in science teaching. They can provide experiences as real to the pupil as are many of the demonstrations and laboratory exercises. Often they surpass the latter in variety, clarity, and pertinency. When properly used they supplement other exercises, fill in gaps, and tie together ideas which belong together. Occasionally a screen experience may well supplant a somewhat fragmentary demonstration or laboratory experience.

One of the most extensive and complete early studies was completed by Wood and Freeman (1929), who conducted an experiment involving more than 3500 pupils studying general science. The desire was to determine the contribution of motion picture films when used as an integral part of classroom teaching procedure in motivated interest, increasing learning, improving descriptive processes, and promoting understanding. Although the results were not as definitive for science as for the other subjects considered, it was concluded that, on descriptive type questions, the gain by the film-using group exceeded that of the non-film-using group by a statistically significant amount. However, based on scores on tests made up of abstract-type questions, the level of achievement of the two groups was about equal. These results were interpreted to mean that students readily learned facts from the use of films but the films did not significantly improve their ability to reason.

In a study by Rulon (1933), designed to determine the effectiveness of sound motion pictures in teaching ninth grade general science, it is reported that:

> In terms of immediate student achievement, our results indicated that the teaching technique employing the motion picture was 20.5 percent more effective, from the instructional standpoint, than was the usual unaided presentation.

Rulon concluded that students who were taught using procedures that involved motion pictures (1) learned a larger quantity of factual information and also (2) improved their thinking ability. During the same period in time Arnspiger (1933) compared the results of teaching natural science with and without the use of sound motion pictures to fifth-grade pupils. His findings were that the test gain scores of the film-using group were significantly higher than those of the group receiving the usual methods of classroom instruction and that the low and high IQ film-using groups earned higher average scores on the final tests than the comparable groups not using films. In summary he stated, "It appears that talking pictures used in this experiment made marked and lasting contributions to learning in natural science units."

A summary by Wittich and Fowlkes (1946) of the research conducted by Clark and Hansen provides further evidence that the motion picture made a positive contribution to the learning of science. Clark concluded that at the college level sound and silent films are as effective as identical lecture-demonstrations in conveying specific information in the field of physical science and in developing ability to think and reason. In his study of the sound film used with students in tenth grade studying biology, Hansen detected a higher level of retention of knowledge among children in the experimental group.

Maneval (1940), in a study to determine the relative value of sound and silent motion pictures in science teaching, found that pupils of higher mental ability tend to learn more when taught by a method involving the use of the silent film and those of lower mental ability tend to benefit more from a method employing the sound film. In this study the silent films involved having the learner read the captions associated with the films. It has been suggested that reading difficulties were overcome partially by the use of the sound films.

The relative effectiveness of sound motion pictures and equivalent teacher demonstrations in teaching general science in the ninth grade was questioned by Smith (1949). His expressed intent was to consider the comparative merits of these two methods of visual presentation. The experimental instructional methods used are described in the following paragraph.

> The film method section was taught using the educational sound motion picture in lieu of teacher demonstrations of any kind. In the demonstration section, no films were used. Demonstrations corresponded as exactly as possible to those shown in the film. Both the film and teacher demonstrations were used in the third sections; thus, students in this section had the benefit of both instructional techniques.

The results he found indicated that there were no real methods differences; students performed consistently regardless of the method employed, and the gains made by the students in both groups were positively related to intelligence. In another study involving a comparison of the effectiveness of films and demonstrations, Tendam (1961) concluded that students who viewed demonstrations on film earned significantly high quiz scores than did the students who viewed the live demonstrations.

Anderson, Montgomery, and Ridgeway (1951) posed a question similar to that studied by Smith; however, they extended their study to the relative values of various multisensory methods in the teaching of high school biology. The control group performed a minimum number of laboratory activities, witnessed only a few demonstrations, and viewed no instructional films.

The film group viewed 18 films, performed no laboratory activities, and witnessed infrequent demonstrations. The laboratory group performed a considerable number of laboratory activities but viewed no films. The film-laboratory group performed a considerable number of laboratory activities and viewed the instructional films. The investigators concluded that the students who received instruction utilizing both films and the laboratory activities earned scores on the Minnesota State Board Examination in Biology that were significantly higher than those earned by students in the control, film, and laboratory groups. When scores earned by other groups were compared, no significant differences in achievement on the criterion instrument resulted. This suggests that learning with films compares favorably with learning with laboratory instruction.

Huffman (1959) conducted a similar study involving four groups of eighth-grade students in general science classes where each class received four weeks of instruction employing a different method: a film group, a lecture group, a demonstration group, and a combination group. The conclusion, based on student achievement was that "there was no significant difference in achievement due to the four instructional methods." In another study involving the use of films as instructional aids in biology, Anderson, Montgomery, Smith, and Anderson (1956) concluded that understanding and application of principles were superior when the specific principles covered in the film received definite emphasis, and that students who viewed the films but did not have the principles stressed were somewhat superior to the control group that did not view the films. The researchers suggested that the results imply that maximum learning can take place when the principles emphasized in the films receive definite consideration.

For a period of time in the late 1950's and early 1960's research in the use of audiovisual methods shifted from the consideration of supplementary and correlational use of audiovisual techniques to the feasibility of presenting complete high school science courses by means of motion picture film. The following studies were mainly stimulated by the production of the Harvey White physics films. In general the basic research question involved testing which method produced superior achievement during one school year of instruction, the conventional method or the film method of instruction. Pella, Stanley, Wedemeyer, and Wittich (1962) conducted a study to determine the effect of the Harvey White physics films on high school students' knowledge of physics and on the high school teachers' knowledge of physics, and to compare the expressed interest in science of the film-using group and the group not using the films. The investigators concluded that (1) the non-film-using and film-using groups showed no significant difference in the amount of physics learned when the test items measured content that was presented in both the films and textbooks; (2) from the standpoint of retention the non-film-using group retained more information than the film-using group after a period of three months; (3) the teachers who saw the films learned a significant amount of physics information above that learned by the non-film-using teachers. On the question of interest, the non-film-using students expressed a significantly higher interest in science than did the film-using students.

Anderson and Montgomery (1959) completed a study similar to the study by Pella et al. and concluded that no difference in achievement existed between the film-using classes and the classes taught by conventional means. They further concluded that "students with above average, average and below average intelligence quotients of the experimental classes did not achieve significantly more than their counterparts in control classes." However, for those students with an IQ of 124 and above the film method was not superior to the conventional method. An evaluation of an introductory chemistry course on film was completed by Anderson, Montgomery, and Moore (1961). The chemistry course consisted of a textbook supplemented by a series of 160 lectures and demonstrations conducted by Professor John Baxter. The study compared the conventional method of instruction with the film method of instruction. The researchers concluded that only 3 of the 17 differences noted were significant and in favor of the film groups. This was especially true when the conclusions were based upon scores earned on the A.C.S.-N.S.T.A. Chemistry Examination. The investigators suggested that films should not replace the regular mode of instruction. Sadnavitch, Popham, and Black (1962), in discussing the results of their study of the retention value of filmed science courses, concluded that no statistically significant differences in the amount of retained information existed between the film-taught and conventionally-taught students in physics and chemistry after a 12-month interval had elapsed.

A recent study completed by Fowler and Brosius (1968) indicated that films can be satisfactorily substituted for actual dissection activities in tenth-grade biology. The investigators evaluated the relative achievement in learning facts, developing problem-solving skills, understanding science, developing attitudes and skill in dissection between a group of students who performed the dissections and a group of students who viewed the dissections on film. The film-using group achieved a higher level of factual knowledge and development of problem-solving skills than the dissection-using group. In the other areas of consideration there were no significant differences in achievement noted.

The majority of the studies reviewed support the position that the use of motion pictures can produce significant results in the learning of science. Several of the studies suggest that the motion picture is as effective as the conventional methods of teaching science.

STUDIES OF THE USE OF STILL PICTURES

The review of related literature thus far has been concerned with the use of motion pictures as a supplement in teaching a science course and as the media of communication for the entire science course. Another group of visual aids to consider is still pictures in the form of a slide film or lantern slide.

Although the motion picture may be valuable in teaching concepts where motion is involved or where continuity of action is important, this media is rather inflexible in that the presentation of the scenes is fixed and cannot be easily controlled by the teacher. With the use of slide film the teacher can devote any amount of time to each frame depending upon its relative importance or complexity. Another advantage to using the slide film is the opportunity for active participation on the part of the students and the teacher. Blanc (1953), discussing the use of audiovisuals in the classroom, stated:

> Slides are one of the first types of projected materials to have been used for science instruction and the development of newer types of materials has not diminished the value of this important teaching aid. The possibilities for making and using slides as visual aids in a unit are great, and the resourceful teacher should capitalize on these values.

Although the slide film is a valuable teaching tool, little research on its use in the teaching of science has been reported. Brown (1928), completed a study in 1928 in which a comparison was made of the relative effectiveness of the motion picture and slide film in teaching the topic of how we hear. He concluded that the slide film was superior to the motion picture as a learning aid. He also stated that the slide film allowed for more opportunities for the teacher and the student to exchange comments. Goodman (1942) completed a study comparing effectiveness of motion pictures and lantern slides in teaching certain concepts in biology. He concluded that the general achievement of the slide-using group exceeded that of the film-using group. The same investigator, in a study involving sixth-grade students, studied the relative effectiveness of a sound motion picture, a silent motion picture, silent film slides, and sound film slides in the teaching of concepts in safety (1943). In this study the silent motion picture group earned the largest gains in test scores for both immediate and delayed recall in all groups. For the high IQ group the silent film slide produced the largest gain in terms of test scores, for both immediate and delayed recall. The silent film slide was also effective with the low IQ group, but the silent motion picture was more effective. In all cases Goodman concluded that the sound motion picture was least effective. On the basis of his research he stated that more attention and recognition should be given to the film slide as a teaching tool. One of the major factors to consider, according to Goodman, is the high cost of motion picture film rental and production and the low cost and ease of production of the film slide.

A study comparing the effectiveness of selected filmstrips and sound motion pictures in teaching soil conservation conducted by Ortgiesen (1954) revealed that filmstrips were significantly more effective than sound motion pictures and both were more effective than printed material alone.

Slides were used by Graham (1944) in the teaching of an astronomy unit in general science. He concluded that the group that received instruction including the use of slides achieved more than the group receiving instruction not including slides.

Romano (1957) used slide films and motion pictures in combination to effectively improve the science vocabulary learning of students in Grades 5, 6, and 7. Students that received science instruction utilizing the slide film and motion picture combination showed larger gains in the science vocabulary acquired than the group that did not receive the combination instruction.

Two separate studies, not directly involving science instruction but having direct relationship to the use of slides in instruction, were completed by Heidgerken and Laner. Heidgerken (1948), found that:

> On the basis of evidence it seems logical to infer that no significant difference in achievement existed between the groups who used the motion pictures and slide films together, the motion pictures alone, the slide films alone, or neither the motion pictures nor the slide films, and any difference which did exist could be attributed to random sampling variation.

Laner (1954) concluded that there was no significant difference between the results of instruction using motion pictures and instruction utilizing filmstrips in the learning and performance of certain skills.

SUMMARY

Few research studies have been reported that answer the question, Can audiovisual materials act as an effective substitute for the laboratory or laboratory activities? The Thirty-first Yearbook of the NSSE (1932) stated that audiovisual material "can provide experiences as real to the pupil as many of the laboratory exercises." The results of the study conducted by Anderson, Montgomery, and Ridgeway (1951) supported the position that direct laboratory work is not essential for achievement in biology. Students who experienced instruction without the benefit of films achieved as well as the laboratory group. One can conclude from the studies by Pella, Stanley, Wedemeyer, and Wittich (1962) and Anderson and Montgomery (1959) that direct involvement in laboratory activity is not necessary for successful achievement in physics. Students who viewed laboratory activities and demonstrations on films achieved as well as students who were directly involved in laboratory activity. According to the study by Sadnavitch, Popham, and Black (1962), direct laboratory experience did not increase the retention value of the learned material. Students who did not have direct experience in the laboratory retained information in physics and chemistry as well as students who had direct laboratory experience. These studies should be given careful consideration since the results were based on the effect of a film course used for an entire school year. Although the results obtained by Fowler and Brosius (1968) were based only on a particular segment of instruction, laboratory dissection, they revealed that students who saw dissection on film achieved as well as, if not better than, students who actually performed the dissection.

Evidence from a number of studies has been presented which indicates that audiovisual material can lead to successful achievement in high school science. It seems that the research studies in which slides were used support the proposition that slide films can be used effectively to teach science and are at least as effective, if not more effective, than instruction utilizing motion pictures. Except for a small number of the studies reviewed, the major emphasis and use of motion pictures and slide films were for supplementary purposes; the audiovisual material was used as an aid in learning rather than as a substitute for a particular learning activity.

The present study is concerned with visual material serving as a replacement for a particular phase of laboratory work, that is, as a substitute for the manipulation phase of laboratory activity. Results of several studies suggest that direct laboratory experience does not seem to be essential for satisfactory achievement in high school science. It is the intent of this paper to determine whether direct manipulation of laboratory equipment is essential to satisfactory learning in science.

III
PROCEDURE

INTRODUCTION

The purpose of this study was to compare two methods of laboratory instruction: the manipulative and the nonmanipulative.

Important to the success of this experiment was the control of as many factors as possible, such as the nature of the subject matter to be learned, level of maturity of the learners, time of day when instruction of the experimental and control groups took place, predicted academic achievement level of the learners, competence of the teachers, and adequacy of the learning environment. The single variable was the presence or absence of the manipulative phase in the laboratory activities used in teaching.

SUBJECT MATTER

The subject matter with claimed reliance on laboratory activities as a tool for learning was that included in the Introductory Physical Science (IPS) course. In the IPS Progress Report (1965), Uri Huber Schaim stated:

> The purposes of the IPS course are two: on the one hand to be a sound foundation for future physics, chemistry and perhaps biology courses; and on the other hand to furnish sufficient nourishment in the essence, the spirit and the substance of physical science to be a good terminal course for those who will not study physical science later on...
>
> There are certain values and skills that can and should be taught in junior high science. First we want to give a feeling for the kind of human effort that is involved in the development of science. We want to put across the point that the root of all science is phenomena and that names come later. We should like the student to get his information from the original source, from nature itself. This calls for real investigation in the laboratory.

It is stated in the preface of the Student's book (IPS, 1967) that

> the method employed to achieve the stated goals is one of student experimentation and guided reasoning on the results of such experimentation. Thus, the laboratory experiments are contained in the body of the text and must be carried out by the students for proper understanding of the course.

The central theme of the IPS course is the study of matter, the development of evidence basic to the development of an atomic model of matter. The emphases in the first three chapters, that require about one semester to complete, are on quantity of matter and the characteristic properties of matter. Specifically the purposes of the IPS course are to provide students with basic laboratory skills, experience in observation, knowledge of how to apply elementary results, and the ability to develop an abstract idea from a concrete situation.

LEVEL OF MATURITY OF LEARNER

The midwestern city school selected as the site for the study offered IPS at the eighth-grade level, therefore this became the maturity level of the population involved. One reason for selecting this school was the fact that the students attending had not been enrolled in science classes in Grade 7 because science was not a part of the seventh-grade curriculum in this city. The science experiences provided in the elementary schools attended by this population are a matter of conjecture.

TIME OF DAY

The criterion that "there must be two IPS classes meeting simultaneously during the hours selected for instruction" was satisfied by using the 10:00 a.m. and 11:00 a.m. class hours. A 50-minute period of instruction was employed for all classes.

ACADEMIC LEVEL OF LEARNERS

The students in the eighth grade of this school were homogeneously grouped according to IQ, performance in Grade 7, and teachers' recommendations as low, average, and above average. Because of the nature of the curriculum offered to the "low" groups, these were excluded from the experiment.

The assignment of the pupils from average and high groups to classes depended in part upon administrative facility and the nature of the electives of the pupils; however, the assignment to science classes was essentially random within the respective groups. The two average groups meeting at 10:00 a.m. and the two above average groups meeting at 11:00 a.m. were selected for the study.

TEACHERS AND FACILITIES

The two male teachers selected had previous experience teaching this IPS course and both had attended a six-week summer institute devoted to the special techniques and skills necessary for teaching the course.

The facilities for teaching included two well equipped classroom-laboratories with dark curtains and audiovisual equipment and the necessary special apparatus in adequate quantities for performing all of the suggested IPS experiments.

DESIGN OF STUDY

The design of this study was a 2 x 2 x 2 factorial, with the factors being treatment, IQ, and sex. The design allowed for the testing of each main effect as well as the two and three factor interactions.

Multiple dependent measures resulted from test scores on the evaluation instruments. These were treated statistically utilizing multivariate, and subsequently, univariate analyses of variance. These analyses were performed by means of Multivariance: FORTRAN Program for Univariate and Multivariate Analysis of Variance and Covariance (Finn, 1967).

> This program performs univariate and multivariate linear estimations and tests of hypotheses for any crossed and/or nested design, with or without concomitant variables. The number of observations may be equal, proportional, the latter including missing observation and incomplete design.

The program offers a large number of options for calculating and displaying information. In this study only the standard routines for calculating univariate and multivariate analyses of variance were performed.

Item statistics and reliability of pretest and posttest data were determined through the use of the Generalized Item and Test Analysis Program (Baker, 1966).

EXPERIMENTAL PROCEDURE

One of each of the pairs of average and high ability classes was designated by random means as the experimental class, and the other as the control class.

The students in the control classes performed the laboratory activities as designed and described by the developers of the IPS course in the teacher's manual. These classes made up the manipulative group.

The students in the experimental classes viewed projected 2 by 2 colored slides which represented sequences of the same laboratory activities as those performed by the manipulative group. At no time did this group manipulate equipment. It was designated as the nonmanipulative group. All other instructional procedures were constant for both groups.

The slides were prepared outside of the class by photographing what were believed by the investigator and the teachers to be the important phases of each laboratory activity. Particular care was taken to insure that each slide correctly represented the activity as it would be seen by the student if he were the performer. To assure the validity of the contents of the slides, the teachers of the course assisted in their preparation by performing the laboratory activities being photographed and suggesting the specific phases to be photographed.

The students in the experimental classes (nonmanipulative group) viewed the pictures of the laboratory sequences and collected data from the slides as projected.

The titles of the experiments completed by the experimental and control groups are:

1. Measurement
2. Distillation of Wood
3. Measuring Volume by Displacement of Water
4. Equal-arm Balance
5. The Precision of the Balance
6. The Mass of Dissolved Salt
7. The Mass of Ice and Water
8. The Mass of Mixed Solutions

9. The Mass of Copper and Sulfur
10. The Mass of Gas
11. The Density of Solids
12. The Density of Liquids
13. The Density of a Gas
14. Thermal Expansion of Solids
15. Thermal Expansion of Liquids
16. Elasticity of Solids
17. Freezing and Melting
18. Micro-melting Point
19. Boiling Point

The effect of teacher bias was minimized by having the two teachers exchange classes at the completion of nine laboratory activities. Teacher A first taught the average ability non-manipulative class and the high ability manipulative class. Teacher B first taught the average ability manipulative class and the high ability nonmanipulative class.

Teacher's guides were prepared to supplement the IPS prepared teacher's materials (Appendix A in Sherman, 1968). These guides were designed to assist the teacher in pursuing a logical sequence in the presentation of the slides, in developing a dialog with the students, and in insuring a reasonable degree of uniformity between classes.

Since the data collected by the students in the experimental classes represented, in effect, the data collected by one team, charts to stimulate class data were included in the teacher's guide. The charts were displayed by means of an overhead projector.

EVALUATION

Introduction

The outcomes possibly attributable to the direct participation in the manipulative phase of the activities were discussed in the introduction (see pages 1–4). It will be recalled that the following outcomes were suggested:

1. An improvement in the student's ability to think critically.
2. An increased understanding of the products and processes of science.
3. An increased interest in science.
4. An increase in achievement related to the knowledge and application of the course content.
5. An increase in the ability to perform specific laboratory skills and techniques.

Instruments were selected on the basis of these five possible outcomes and it was assumed that the student's score on each was an indication of his level of achievement of that particular objective. All instruments were administered both before and after instruction.

Instruments Selected

1. Critical Thinking. The scores on Watson and Glaser's Critical Thinking Appraisal, Form Zm, (1964b) are proported to indicate levels of critical thinking ability related to:

1. the definition of problems
2. the selection of pertinent information for the solution of a problem
3. the recognition of stated and unstated assumptions
4. the formulation and selection of relevant and promising hypotheses
5. the drawing of valid conclusions and judging the validity of inferences.

Judgments of qualified persons and results of research studies support the authors' belief that the items in the Critical Thinking Appraisal represent an adequate sample of the above five abilities and that the total score yielded by the test represents a valid estimate of the proficiency of individuals with respect to these aspects of critical thinking.

The Watson-Glaser instrument is made up of five subtests: (1) inference, (2) recognition of assumptions, (3) deduction, (4) interpretation, (5) evaluation of arguments. Although the test is designed for individuals who have completed the ninth grade or its equivalent, it has been reported as being successfully used with eighth-grade students (cf. Yager and Wick, 1966).

2. Understanding Science. The Test on Understanding Science (TOUS), Form Jx, was used to measure the understanding of science possessed by the students. This instrument consists of 45 items of the multiple-choice type, designed to sample student understanding of the scientific enterprise, scientists, and the methods and aims of science (Carrier and Klopfer, 1964). Although TOUS, Form Jx, is an experimental test, extensive standardization operations have been conducted. The authors of TOUS suggest that it has possible application in teaching experiments where these understandings are compared. TOUS, Form Jx, was modified for junior high school students by Carrier and Klopfer from the high school form developed by Cooley and Klopfer.

3. Interest in Science. The expression of interest of individuals depends upon many things, such as age, the interval between testings, what happens to the student during the interval, and particularly how strong his interests are, (Kuder, 1964). For the purpose of this study only the scores on the science part of the Kuder

General Interest Survey, Form E, (1964) were recorded although the student responded to the entire test of 10 categories. An individual's score on the Scientific Scale of the Kuder General Interest Survey was derived from his fixed-choice response to 33 triads and had a maximum possible raw score value of 62.

4. Achievement Test. The IPS Achievement Test (Chapter I-III) 1964 was employed to determine the degree to which the students achieved the academic objectives of the course as viewed by the developer. Although the course is designed primarily for the ninth grade, results of previous studies revealed that it has also been used with eighth-grade students with about equal success (IPS 1965).

The Unit I Test included 26 items of the multiple-choice type that pertained directly to the first three chapters.

> Since the purpose of the test was to assess student attainment of the course objectives, a crucial requirement was that the test questions appraise student possession of the same understanding and abilities that the course is designed to instill. This crucial requirement was met simply but effectively; the persons who developed the course materials also developed the tests [IPS, 1965].

The test reflected the plan that laboratory activities are an integral part of the text and of equal importance with the other phases.

5. Laboratory Skill Test. A laboratory skill test (Appendix A) was developed in cooperation with the teachers who were teaching both groups. Several skills were identified as being necessary for the successful completion of the designated laboratory exercises. These skills were: (1) the use of linear metric measure, (2) the use of the bead balance and the triple beam balance, (3) the ability to read a graduated cylinder, (4) the ability to determine volume by water displacement, (5) and the ability to read a Celsius thermometer.

The test consisted of seven items that included 16 separate skills with a total point value of 41. The relative point value for each item was determined by considering the relative emphasis on each skill in the performance of the laboratory exercises. Using this method, it was determined that 15% of the exercises used linear metric measure, 45% of the exercises required correct use of a balance, 15% of the exercises involved correct reading of a thermometer, and 25% of the exercises required the correct determination of volume.

The test was of the performance type and was administered in the laboratory. In order to make it possible for all students to complete the seven items on the test in one class period, four sets of the items for each station were available. Students had a timed period of five minutes to complete the designated skill at each station.

6. IQ Test. The Kuhlmann-Anderson Test, Form G (1960), was administered at the beginning of the fall term to determine the IQ of the students.

Evaluation Instruments Summary

The evaluation instruments used in this study are listed in Table 1. It should be noted that, except for the Laboratory Skill Test, the instruments used are commercially available. Except for the Kuder General Interest Survey, the reliabilities reported were determined from the test data accumulated in this study. The Laboratory Skill Test consisted of only a very few items, contributing in part to the low reliability; it may be noted that a test of 100 similar items would have an estimated reliability of .85 (Spearman-Brown formula from Cronbach, 1960).

Table 1

Reliabilities of Tests

Test	Number of Items	Reliability[1]
Watson-Glaser Critical Thinking	100	.77
Test on Understanding Science	45	.67
IPS Achievement Test (Ch. I-III)	26	.74
Laboratory Skill Test (41 points)	16	.48
Kuder General Interest Survey (62 points)	33	.88[2]

[1]Reliability reported is based on test data from this study unless noted otherwise.

[2]Reliability stated in the manual.

Administration of Instruments

The five instruments utilized were administered to the 100 students as pretests in early September 1967, and as posttests in late

January 1968. Because of the lapse of time between testing, no attempt was made to change test forms.

Teacher Evaluation Form

A Teacher Evaluation Form (Appendix B) was prepared for use during each laboratory activity as a means of determining teacher judgments concerning whether or not the slides and lessons accurately represented the laboratory experiment in the course and how the students reacted to the lesson and slides. The teachers were requested to complete the form independently at the completion of each activity. In addition to this specific information there were opportunities for the teachers to make related comments.

IV
RESULTS

The analyses of the data related to this problem are presented under the six headings of intelligence quotients, critical thinking, understanding science, laboratory skills, achievement, and interest. Also presented are summaries of the multivariate analysis and the Teacher Evaluation Forms.

INTELLIGENCE QUOTIENTS OF THE GROUPS

With the exception of the presence of a larger number of high ability students in the manipulative group than the nonmanipulative group, the student IQ's within the two groups were similar (Figure 1). The number of students with higher IQ's in the manipulative group may account for the fact that the mean IQ of this group is significantly higher than that of the nonmanipulative group (Table 2). The correlation of the IQ of each group with test scores on each of the five test instruments reveals that the IQ is not a source of variance.

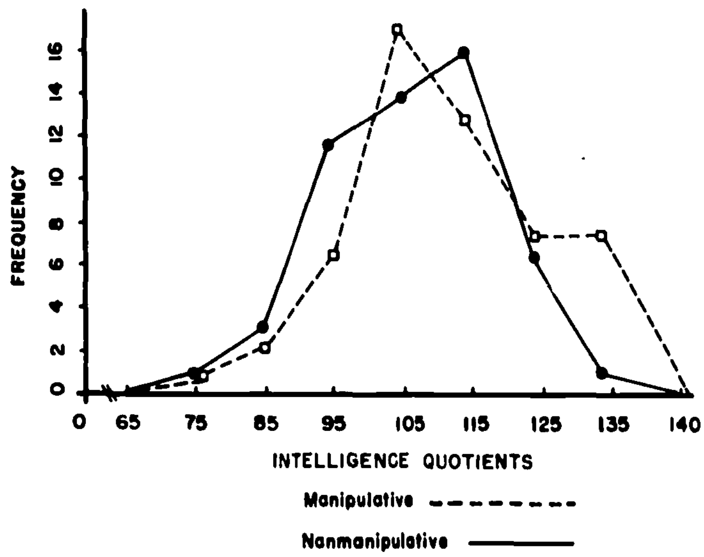

Figure 1. Frequency Distribution of Intelligence Quotients of 50 Pupils in Manipulative and 50 Pupils in Nonmanipulative Groups.

Table 2

Means, Standard Deviations, and Ranges of the Intelligence Quotients of Pupils in Manipulative and Nonmanipulative Groups

	Manipulative Group		Nonmanipulative Group	
	$\overline{X}$	S.D.	$\overline{X}$	S.D.
IQ	113.2	13.6	107.9	12.5
Range	79-136		75-136	
Significance of IQ difference between means		F=4.09	(Significant at $p < .05$) *	

Significant value for $p < .05$ $F(1,48)$ $(.05) \geq 4.04$ *

ANALYSIS OF THE CRITICAL THINKING TEST DATA

It is noted from the frequency distributions and means of pretest scores given in Figure 2 and Table 3 that the two groups were similar in terms of critical thinking ability prior to the period of instruction.

Following the period of instruction, the mean gain score of the manipulative group exceeded that of the nonmanipulative group by 1.9 points, a difference that is not signicant (Table 4). Although the posttest score frequency distributions were similar (Figure 3), the gain between pre- and posttest administrations within the manipulative group was significant whereas the gain for the nonmanipulative group was not significant (Table 3).

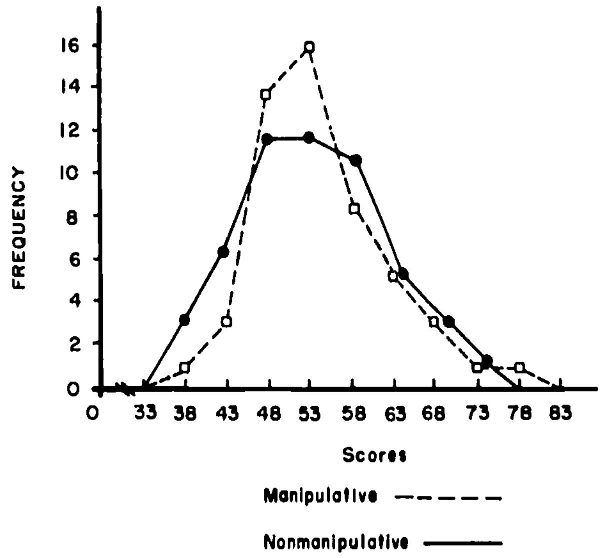

Figure 2. Frequency Distribution of Watson-Glaser Critical Thinking Pretest Scores of 50 Pupils in Manipulative and 50 Pupils in Nonmanipulative Groups.

Table 3

Means, Standard Deviations, and Gain Scores of the Watson-Glaser Pretest and Posttest Scores Earned by Manipulative and Nonmanipulative Groups

(Total Possible Score 100)

	Manipulative Group		Nonmanipulative Group	
	$\overline{X}$	S.D.	$\overline{X}$	S.D.
Pretest	54.2	7.8	53.0	8.0
Posttest	59.0	9.9	55.9	8.7
Gains	4.8		2.9	
Significance of the gains	F=7.21 (Significant, $p < .01$) *		F=2.11 (Not significant) *	

Significance level F(1,48) (.01) $\geq$ 7.19 *

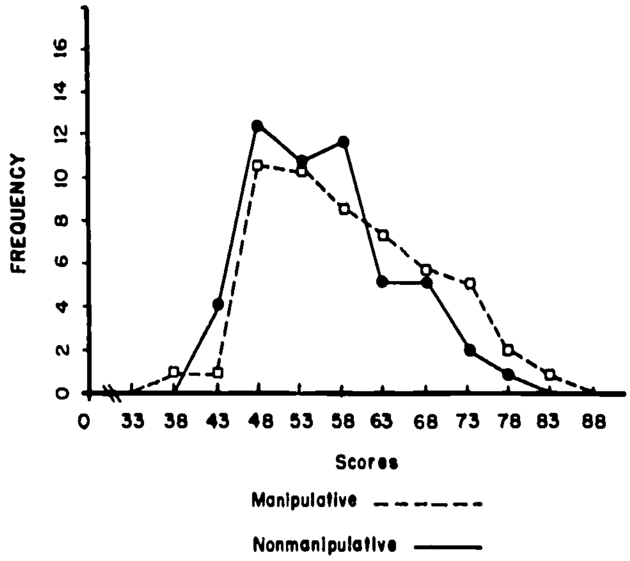

Figure 3. Frequency Distribution of Watson-Glaser Critical Thinking Posttest Scores of 50 Pupils in Manipulative and 50 Pupils in Nonmanipulative Groups.

ANALYSIS OF UNDERSTANDING OF SCIENCE TEST DATA

The pretest revealed little difference between the manipulative and nonmanipulative groups prior to instruction. Although the manipulative group included more students in the upper range of scores, it can be seen in Table 5 that a difference of only 1.4 test points existed between the pretest means.

From Figure 4 and Table 5 it can also be noted that the frequency distributions and mean scores after instruction were similar. Examination of Table 5 reveals that both groups made significant gains; however, the gains of the two groups were not significantly different (Table 6).

ANALYSIS OF LABORATORY SKILLS TEST DATA

Before the period of instruction the two groups performed at similar levels on the laboratory skills test (Table 7).

Table 4

Summary of the Analysis of Variance of Gain Scores on the Watson-Glaser Pretest and Posttest (Alpha .05)

Variable	MS (Between)	df	F (Univariate)	F (Critical)	P Less Than
Watson-Glaser Difference	108.1210	1,92	2.4014	3.92	0.1247

Table 5

Means, Standard Deviations, and Gain Scores of the TOUS Pretest and Posttest Scores Earned by Manipulative and Nonmanipulative Groups

(Total Possible Score 45)

	Manipulative Groups		Nonmanipulative Groups	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Pretest	22.7	5.7	21.3	6.1
Posttest	25.0	5.2	24.1	5.0
Gains	2.3		2.8	
Significance of the Gains	F=6.17 (Significant $p < .05$) *		F=5.94 (Significant $p < .05$) *	

Significance level F(1,48) (.05) ≥ 4.04 *

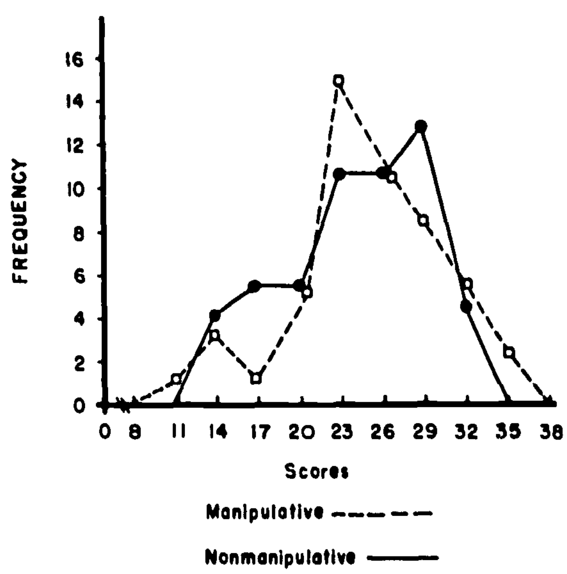

Figure 4. Frequency Distribution of TOUS Posttest Scores of 50 Pupils in Manipulative and 50 Pupils in Nonmanipulative Groups.

Table 7

Means, Standard Deviations, and Gain Scores of the Laboratory Skill Pretest and Posttest Scores Earned by Manipulative and Nonmanipulative Groups

(Total Possible Score 41)

	Manipulative Group		Nonmanipulative Group	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Pretest	10.1	4.8	9.9	6.0
Posttest	27.2	7.5	22.7	8.0
Gains	17.1		12.8	
Significance of the Gains	F=195.0 (Significant $p < .01$) *		F=99.87 (Significant $p < .01$) *	

Significance level F(1,48) (.01) ≥ 7.19 *

Comparisons of the two posttest means and frequency distributions of the posttest scores (Table 7) reveal that the posttest performance by the manipulative group exceeded that of the nonmanipulative group by 4.3 test points. It should be noted that even though the nonmanipulative group did not directly perform any of the tasks represented in the laboratory skill test, they were able to make a significant improvement (Table 7).

The gain scores on the laboratory skills test earned by the manipulative group were significantly greater than those of the nonmanipulative group (Table 8).

ANALYSIS OF IPS UNIT I ACHIEVEMENT TEST DATA

The similarities of the two groups in terms of academic knowledge as defined by IPS, prior to instruction, are apparent from Table 9.

Following instruction both groups earned scores indicating significant average gains in

Table 6

Summary of the Analysis of Variance of Gain Scores on the TOUS Pretest and Posttest (Alpha .05)

Variable	MS (Between)	df	F (Univariate)	F (Critical)	P Less Than
TOUS Difference	7.9485	1,92	0.3262	3.92	0.5693

Table 8

Summary of Analysis of Variance of the Gain Scores on the Laboratory Skill Pretest and Posttest (Alpha .05)

Variable	MS (Between)	df	F (Univariate)	F (Critical)	P Less Than
Laboratory Skill Difference	315.6768	1,92	6.6438	3.92	0.0116

Table 9

Means, Standard Deviations, and Gain Scores of the IPS Pretest and Posttest Scores Earned by Manipulative and Nonmanipulative Groups

(Total Possible Score 26)

	Manipulative Group		Nonmanipulative Group	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Pretest	7.6	3.2	7.1	3.0
Posttest	13.3	4.6	12.3	4.3
Gains	5.7		5.2	
Significance of the Gains	F=50.48 (Significant beyond p < .01) *		F=30.99 (Significant beyond p < .01) *	

Significance level $F(1,48)$ (.01) $\geq$ 7.19 *

achievement (Table 9); however, a definite similarity remained in the frequency distributions and means for the two groups. From Table 10 it can be seen that the gain scores earned by the students in the two groups were not significantly different.

ANALYSIS OF THE KUDER GENERAL INTEREST SURVEY DATA

When the scores earned by the two groups on the science interest section prior to instruction are compared, it is found that the manipulative group registered a significantly greater interest in science (Table 13). Comparison of Tables 11 and 12 reveals that this pretest difference in interest may be attributable to the higher measured interest of the boys in the manipulative group. A significant difference existed between the pretest mean scores of the boys in the manipulative and nonmanipulative groups but not of the girls.

Note from Table 11 that the boys in the manipulative group also had a higher level of interest than the boys in the nonmanipulative group following instruction and that these scores were again significantly different. Also the posttest mean scores earned by the girls in the two groups were again not significantly different (Table 12).

An examination of the mean scores given in Table 13 reveals that both the manipulative and nonmanipulative groups experienced a decrease in mean scores earned following instruction; however, this loss was not statistically significant (Table 14).

SUMMARY OF MULTIVARIATE ANALYSIS

A multivariate analysis using treatment gain scores, IQ, and sex was completed in order to provide a comprehensive simultaneous treatment of all of the variables. An examination of Table 15 discloses that (1) the only significant difference that existed within the data was for IQ with students of the high ability group performing significantly better than students of the

Table 10

Summary of the Analysis of Variance of the Gain Scores on the IPS Pretest and Posttest (Alpha .05)

Variable	MS (Between)	df	F (Univariate)	F (Critical)	P Less Than
IPS Difference	3.6702	1,92	0.2627	3.92	0.6095

Table 11

Means, Standard Deviations, and Losses of the Kuder Interest Survey Pretest and Posttest Scores Earned by Boys of Manipulative and Nonmanipulative Groups

(Total Possible Score 62)

	Manipulative Group		Nonmanipulative Group	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Pretest	48.6^{a}	7.7	42.0^{a}	9.4
Posttest	45.7^{b}	10.5	39.6^{b}	11.0
Losses	2.4		2.9	
Significance of the Losses	F=2.83 (Not significant) *		F=.03 (Not significant) *	

Significance level $F(1,23)$ $(.05) \geq 4.28$ *

Significance of pre- and posttest means for boys of manipulative and nonmanipulative groups

a. Pretest	F=55.1	(Significant, $p < .01$)$^{\nabla}$
b. Posttest	F=54.0	(Significant, $p < .01$)$^{\nabla}$

Significance level $F(1,50)$ $(.01) \geq 7.17$ $^{\nabla}$

average ability group; (2) the sex of the student did not appear to be related to the performance; (3) there was no significant difference between gain scores earned by pupils receiving different treatments; and (4) there were no significant interactions.

SUMMARY OF TEACHER EVALUATION FORM

No attempt was made to treat the results of the Teacher Evaluation Form in a statistical manner since the data obtained were purely subjective in nature. Although the forms were completed independently, there was a high level of agreement between the two teachers. Except in a few specific situations the teachers agreed that (1) the slides and lessons accurately represented the activities, (2) the use of the slides apparently did not interfere with the day-to-day routine or disrupt the class in any way, (3) the students were able to follow the activities using the slides, and (4) students were able to adequately complete their laboratory notebooks as well as any homework related to the activities.

Table 12

Means, Standard Deviations, and Losses of the Kuder Interest Survey Pretest and Posttest Scores Earned by Girls of Manipulative and Nonmanipulative Groups

(Total Possible Score 62)

	Manipulative Group		Nonmanipulative Group	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Pretest	29.7^{a}	12.0	30.9^{a}	13.2
Posttest	27.0^{b}	11.9	30.5^{b}	12.3
Losses	2.7		.4	
Significance of the Losses	F=.41 (Not significant) *		F=2.36 (Not significant) *	

Significance level $F(1,21)$ $(.05) \geq 4.32$ *

Significance of pre- and posttest means for girls of manipulative and nonmanipulative groups

a. Pretest	F=.41	(Not significant)$^{\nabla}$
b. Posttest	F=2.36	(Not significant)$^{\nabla}$

Significance level $F(1,46)$ $(.05) \geq 4.05^{\nabla}$

The opinions expressed by the teachers with regard to the individual lessons were: (1) the students who viewed the slides exhibited a lower level of interest in the activities and this resulted in a lack of interest in the course; (2) the viewing of the slides did not allow the students to actually manipulate the equipment, and therefore one of the important objectives of the course could not be realized; (3) the opportunity was missing for students to exhibit some creativity by trying out new ideas that were stimulated by the laboratory activities; and (4) their own interest was much lower in the teaching of the slide-viewing group.

SUMMARY

The results of analyses of effects and interactions obtained through the application of univariate and multivariate analysis of variance techniques on the five criterion scores were:

1. The students in the manipulative group earned significantly higher gain scores on the Laboratory Skill Test than students in the nonmanipulative group.

Table 13

Means, Standard Deviations, and Losses of the Kuder Interest Survey
Pretest and Posttest Scores Earned by Manipulative and Nonmanipulative Groups

	Manipulative Group		Nonmanipulative Group	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Pretest	40.3[a]	13.6	36.2[a]	12.7
Posttest	37.5[b]	14.5	34.9[b]	12.5
Losses	2.8		1.3	
Significance of the Losses	F=2.31 (Not significant) *		F=0.1 (Not significant) *	

Significance of pre- and posttest means for manipulative and nonmanipulative groups.

a. Pretest	F=13.1	(Significant, $p < .01$)▽
b. Posttest	F= 2.0	(Not significant) *

Significance levels F(1,80) (.05) ≥ 3.96 *
F(1,80) (.01) ≥ 6.96▽

Table 14

Summary of the Analysis of Variance of the Losses for the
Kuder General Interest Survey Pretest and Posttest (Alpha .05)

Variable	MS (Between)	df	F (Univariate)	F (Critical)	P Less Than
Kuder Interest Difference	51.0472	1,92	0.7571	3.92	0.3866

Table 15

Tests of Significance (Multivariate Analysis)

Source	F	df	Probability
Treatment	1.8878	5,88	$p < .1045$
Sex	1.5933	5,88	$p < .1704$
IQ	6.2201 *	5,88	$p < .0001$
Interaction			
Treatment x Sex	1.0831	5,88	$p < .3754$
Treatment x IQ	1.1704	5,88	$p < .3302$
Sex x IQ	1.3660	5,88	$p < .2449$
Treatment x Sex x IQ	1.4707	5,88	$p < .2075$

* Significant at the indicated level

2. The gain scores earned on the Watson-Glaser Test of Critical Thinking, IPS Achievement Test, Test on Understanding Science, and the losses on the Kuder General Interest Survey by the manipulative and nonmanipulative groups were not significantly different.

3. Students with high IQ's performed at a significantly higher level on all instruments than did students with average IQ's, regardless of treatment.

4. There were no significant differences due to interactions, sex or treatment.

V
CONCLUSIONS AND IMPLICATIONS

CONCLUSIONS

Within the limitations of the criteria and experimental design employed in this investigation, evidence is provided to support the following conclusions:

1. No significant differences in student achievement resulted from the treatment—manipulative or nonmanipulative laboratory instruction—as shown by test scores in the following areas:
   a. critical thinking skills
   b. understanding of science
   c. academic achievement of knowledge and concepts presented in IPS
   d. the development and expression of the interest in science
2. The manipulative method was significantly superior to the nonmanipulative method of utilizing the laboratory for the development of selected laboratory skills.
3. Students with high IQ's learned more than students with low IQ's as a result of studying the IPS course as reflected by all test scores earned.
4. Achievement using the IPS course is not related to sex.
5. There were no significant interactions between:
   a. method of instruction and sex
   b. IQ and sex
   c. method of instruction and IQ
   d. method of instruction, sex, and IQ
6. The academic achievement and performance of the students in the nonmanipulative group did not support the view expressed by the teachers that the manipulatory method of laboratory instruction is necessary for motivation and satisfactory learning of science as defined by the IPS course.
7. The IPS course does not appear to stimulate student interest in science after one semester of instruction.

IMPLICATIONS

The purpose of this investigation was not to reflect upon the importance of the laboratory as an instructional tool in the teaching of science but rather to determine whether the manipulative aspect contributes in the commonly hypothesized ways. The results appear to support the view that certain learning behaviors that have in the past been more specifically associated with the direct manipulatory phase of the laboratory can be attained without the manipulative phase being present. This raises the age-old question, "What must the student experience directly in order for the desired learning to take place?" Although results from this study do not answer this question completely, they do suggest that further experimentation in this direction is necessary.

In the present investigation, each class acted as a team, thinking and analyzing together, under the direction and encouragement of the teacher. What would the results have been if each student or each pair of students had been taught using the indirect nonmanipulatory method using individualized instructional techniques? The answer to this question invades the realm of independent study, computer assisted instruction for the laboratory, and the autotutorial approach to learning. It may be true that many of the facts, concepts, and principles in science can be learned without direct participation in the laboratory. In the place of laboratory exercises, several real investigative laboratory experiences could be completed. Further research needs to be completed before these questions can be answered.

APPENDIX A

LABORATORY SKILL AND TECHNIQUE TEST

Test I

Equipment: A 1/2 meter stick, rectangular piece of wood, a cube.

Instructions: You are to measure the length of each object accurately to the nearest tenth of a meter, the nearest whole centimeter, and the nearest whole millimeter.

Criteria: Accuracy of measuring and correct measuring technique.

Test II

Equipment: Equal arm-balance with all riders at zero, box of beads, two objects.

Instructions: Determine the mass of each object to the nearest whole bead.

Criteria: Accuracy of determining mass.

Test III

Equipment: 10 cm^3 graduate, 50 cm^3 graduate, two different quantities of colored water.

Instructions: Determine the volume in cubic centimeters of water in each container to the nearest whole cubic centimeter.

Criteria: Correct measurement of volume of each liquid.

Test IV

Equipment: A triple beam single pan balance with all riders at zero, two objects.

Instructions: Determine the mass of each object to the nearest gram.

Criteria: Correct determination of mass.

Test V

Equipment: Two centigrade thermometers, three materials of different temperatures.

Instructions: Determine the temperature of each material to the nearest whole degree centigrade.

Criteria: Accurate reading of thermometers.

Test VI

Equipment: Triple beam balance with all riders at zero, a paper cupcake container, sand.

Instructions: Using the proper technique find the mass of this sand to the nearest whole gram.

Criteria: Accurate determination of mass as well as proper technique of using the balance.

Test VII

Equipment: 50 cm^3 graduated cylinder with water, a stone.

Instructions: Determine the volume of this stone to the nearest whole cubic centimeter.

Criteria: Correct determination of the volume.

ANSWER FORM

______________ Name

______________ Period and Teacher

A B C D Test group (circle)

Test I

__________ length of object A in meters
__________ length of object A in centimeters
__________ length of object A in millimeters
__________ length of object B in meters
__________ length of object B in centimeters
__________ length of object B in millimeters

Test II

__________ mass of object A in beads
__________ mass of object B in beads

____
Name

____
Period and Teacher

A B C D
Test group (circle)

Test III

__________cubic centimeters of liquid A
__________cubic centimeters of liquid B

Test IV

__________mass of object A in grams
__________mass of object B in grams

Test V

__________degrees for thermometer A
__________degrees for thermometer B

Test VI

__________mass of sand in grams
__________correct technique (have teacher check and initial)

Test VII

__________volume of stone in cubic centimeters

APPENDIX B
TEACHER EVALUATION FORM

EXPERIMENT TITLE______________________

EXPERIMENT NUMBER____________________

Dates experiment performed with test classes (include introduction to completion):

____

Dates experiment performed with regular classes (include introduction to completion):

____

SLIDES:

Do they represent the experiment? Yes No
If no, why not?

Are they complete? Yes No
If no, what is missing?

Does the technique of working with the projector interfere with your teaching the class? Yes No
If yes, why?

Do you feel that through the use of the slides your objectives for the experiment were attained as well as with the actual experiment? Yes No
If no, why not?

STUDENTS:

Were the students able to follow the experiment using the slides? Yes No
If no, why not?

Did use of the slides create or cause any additional discipline problems? Yes No
If yes, of what nature?

Did the students who used the slides react satisfactorily in discussion? Yes No

Do you feel that the students who used the slides were less interested in the experiment? Yes No

Were students who used the slides able to satisfactorily record the data and write up the experiment? Yes No
If no, why not?

Were students who used the slides able to satisfactorily complete any homework associated with the experiment? Yes No
If no, why not?

LESSON:

Did the lesson satisfactorily represent the experiment? Yes No
If no, where did it fail?

Was the lesson complete enough to allow you to satisfactorily fulfill the objectives of the experiment? Yes No
If no, what was missing?

Did the lesson correlate well with the slides? Yes No
If no, where did the correlation break down?

Did you feel that the lesson restricted your teaching of this experiment? Yes No
If yes, how?

GENERAL:

Do you feel that the experiment as presented by the lesson and slides satisfactorily reached the objective that you established for this experiment? Yes No
If no, which did it fail to meet?

ANY ADDITIONAL COMMENTS AND/OR IRREGULARITIES: (e.g. fire drills, improper functioning of projector)

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