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The relative effectiveness of the lecture-demonstration method and an experimental method in the teaching of general science.

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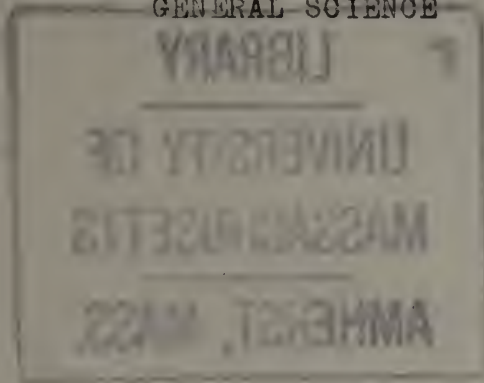
THE RELATIVE EFFECTIVENESS
OF THE LECTURE-DEMONSTRATION METHOD
AND AN EXPERIMENTAL METHOD
IN THE TEACHING OF GENERAL SCIENCE

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THE RELATIVE EFFECTIVENESS OF THE LECTURE-DEMONSTRATION
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GENERAL SCIENCE



Saul G. Gruner

Thesis submitted for degree of Master of Science
Massachusetts State College
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INTRODUCTION

CHAPTER I

INTRODUCTION

A great number of books and magazine articles have been written on the general theme "How to Teach Science". But in spite of all the literature that has been written, the problem of how to teach science most effectively is still a major problem in educational circles. As time goes on, this problem grows more and more important because science is becoming more and more a fundamental part of secondary education.¹ Now that almost all colleges demand that entering students have studied some science, now that school committees are making more and more provision for science courses,² now that we live in an age that is becoming more and more scientific, it is no wonder that science teachers are greatly concerned with the problem "How shall I teach Science?".

(1) Aims in teaching science---Before a science teacher can attempt to answer this question, he must be able to recognize effective teaching, the factors contributing toward it, and the objectives it must attain. Now, each and every science course has some particular aims or objectives, but most of the sciences that are taught in high schools--General Science, Chemistry, Biology, Physics, Astronomy, Health--have several

1. Obourn, Ellsworth S., "The Use of the Text Book in the Effective Learning of General Science". School Science and Mathematics, XXXV, (March 1935), pp 285-291.
2. Webb, Charles S., "The Teaching of Advanced Science Using the Demonstration Method". School Science and Mathematics. XXXVIII, (January 1938), p.27

common objectives. These, as summarized by Frank³, are:

1. To impart a certain amount of factual knowledge which can be used as tools in life.
2. To develop more highly specialized powers, habits, skills, and abilities.
3. To discover pupils with exceptional ability in the technical fields and prepare them for specialization.
4. To develop desirable ideals, attitudes, tastes and disciplines, which each of the sciences makes possible.
5. To rationalize the scientific attitude, produce a confidence in science, and a desire to go forward.
6. To prepare some pupils for the semi-skilled occupations.
7. To develop the ability to think in terms of the materials and operations of science.
8. To carry the pupil's interest to the point of intellectual independence.

It is assumed that effective teaching is that which best attains these aims of science courses.

(2) Aims and subject matter--The great amount of factual material involved in science courses makes the science teachers' job a difficult one. Other than eliminate some out-of-date material, there is little that can be done to decrease the amount of subject matter because everything in the aims of science teaching--from appreciations to understanding of principles--is dependent on a knowledge of facts. Investigators in the field of Science Education seem to have realized this and have devoted their efforts chiefly to teaching methods.

(3) Aims and their realization--The great quantity of literature and experimentation in science education is also a good indication of the dissatisfaction of many teachers in realizing the aims of their courses. A careful analysis of the

3. Frank, J. O., How to Teach Science, Philadelphia, P. Blakiston's Son and Co., (1926) pp. 42-43.

situation shows that if the aims of science courses are not being realized, three--or any one of three-factors might be at fault:

1. the teacher,
2. the pupils,
3. the method of teaching.

A great deal of the success of any course depends on the quality and qualifications of both the teacher and the pupils of that course. But it is not the purpose of this study to discuss these particular phases of the educational problem; and therefore let it stand granted that the teachers and pupils--with their individual differences--are of primary importance, and that their capability might well serve as the subject of close investigation.

(4) Methods in general--The method that a teacher uses to present material to his class is also of great importance. It must be remembered that in his teaching, a teacher must constantly keep in mind the objectives of his course. In order to accomplish these aims, the teacher must, consciously or unconsciously, employ some method or methods. A glance at a partial list of methods that have been suggested and experimented with shows that the problem is, indeed, complicated. There are many books, theses, and periodical articles describing:

1. Individual Instruction,
2. Text-book Methods,
3. Lecture Methods,
4. Laboratory Methods,
5. the Lecture-demonstration Method,
6. the Project Method,
7. Socialized procedures,
8. Visual Methods,
9. and more, less famous progressive methods.

And so the teacher is confronted with the problem "which of the many available methods shall I use?". The method chosen must be one which takes into consideration the pupils' abilities, their interests, and their needs. Many teachers have turned to and are using the lecture-demonstration method; for by this method they feel that they are obtaining as good results as they possibly can. Another reason for the great use of this method is that many teachers have little faith in more progressive methods and think that the amount and thoroughness of the work accomplished is reduced if the class activity centers around the pupil and not the teacher.

(5) Weaknesses in present methods--As has already been indicated, a great amount of work has been done in the study of methods of teaching science. But in spite of all the experimentation that has been done, the cure-all of educational ills--as far as method is concerned--does not seem to have been found. Almost any science teacher will admit that:

1. his pupils are not learning and retaining as much factual material as they might,
2. he has difficulty in setting a suitable pace for the class,
3. he has difficulty in keeping the lasting interest of the class, and
4. his pupils look upon the study of science as a lot of hard work.

A careful analysis of these difficulties brings to light one cause which perhaps is the keynote of the whole problem--the methods being used are not adequately handling the large amount of factual material that must be learned.

(6) The method used in this experiment--An examination of the literature that has been written shows that, even though

the lecture-demonstration method is preferable to other methods for certain purposes, in general, these other methods have their good points too; and since the problems of science teaching exist in any of the methods, reason indicates that no one should be favored above another. The question then arises, "why not make a method to order, a method which is a combination of some of the best ideas in all of the others, and thereby eliminate some of the teaching difficulties?". The "experimental" method of this study is such a method. Basically, it is constructed (1) to allow pupils a great amount of freedom in their work, and (2) to make science appeal to the interest of the pupil. Upon sustained interest depend the other elements of success. A child that is interested in a subject will certainly do better work and learn more than if he were not interested in it. This strikes directly at the desired end--the bringing out of the best work that a pupil can do. Educational psychologists maintain that learning is intimately bound up with interest, seeing, doing, success in doing, competition, desire to be important, and reward. ^{4a} And it was with careful consid-
⁴eration of these principles that the "experimental" method was developed. The method is one that by no means limits or inhibits the work of any pupil; it rather encourages as much as

4. See Chapter III, The Experimental Method

4a. Struck, Theodore, Creative Teaching, New York, John Wiley & Sons, (1935), pp. 152-153.

Ruch, Floyd L., Psychology and Life, Chicago, Scott, Foresman & Company, (1937), pp. 524-596.

one can do. The spirit of competition, the element of pupil importance, and the desire to appear bright--or at least, not to appear dull--are bound to make most pupils extend themselves. The theoretical effect of all this on pupil interest, and the consequent performance, in a course is obvious.

However, the skeptical teacher might rightly ask, "Will the pupils really take a greater interest in the course? Can a teacher get as much material across to this class by this method as by the lecture-demonstration method? Will this method work out in actual practice?" It is the purpose of this investigation to answer these questions and to compare the relative effectiveness of the "experimental" method with the effectiveness of the usual lecture-demonstration method in the teaching of general science factual material.

HISTORICAL REVIEW

CHAPTER II
HISTORICAL REVIEW

A review of the literature that has been written concerning method in science education produces very few previous works on freedom methods. However, much has been written concerning the various methods that serve as a basis of the "experimental" method. In 1935, Barnard¹ made a review of the learning studies in science. Another review of the literature concerning science method was published by Duel² in 1937; and still another review of the same field was published by Noll^{2b} in 1939. These studies are classified and summarized in the following sections.

(1) Laboratory and lecture methods--One of the earliest studies published was that of Allen³, who carried out an experiment to determine whether an "informal problem" method was more effective in assimilative learning than the "text-book" method. Allen defined the "informal problem" method as a method in which most attention is focused on a few central facts and principles and in which more time is take for application and assimilation with a corresponding decrease in content to be recited on.

1. Barnard, J. Darrell, An Investigation to Determine the Relative Effectiveness of Two Methods of Teaching General Science.
2. Duel, A. W., "Measureable Outcomes of Laboratory Work in Science", School Science and Mathematics, XXXVII pp. 968-973.
3. Allen, J. M., "Some Experiments in High School Instruction", The School Review, XXII, (Jan. 1914), pp. 26-34.
- 2b. Noll, V. H. The Teaching of Science in Elementary and Secondary Schools, Chapter IV.

There were two parts to the experiment:

- a. The experimental group was a group of high school freshmen, beginners in general science. Recitations were conducted by the "informal problem" method, in which questions asked by the teacher were required to be answered completely, accurately, and clearly by the pupil. Each pupil had to stick to the problem until he solved it. After eight weeks, following a three day recitation on the barometer, an assimilative test was given without warning. A physics class of twenty-one girls, who had studied the barometer, also took the same examination. The freshmen scored ninety-six percent to the seniors nineteen percent in correct answers.
- b. Six randomly selected freshmen of the elementary science class were placed in a junior-senior physiology class during a period in which some new material was taken up under the "informal problem" method. On the next day, four comprehensive questions were given. The best juniors and seniors did not score as high as the freshmen. This was supposed to show that students trained under the "informal problem" method can reason in other sciences, better than older persons not so trained. Barnard¹ thinks that this study is of little value because it contained many uncontrolled conditions.

In 1918, Wiley⁴ published the results of an experiment which studied the effectiveness of the "text-book-recitation", the "lecture", and the "laboratory" methods with the best possible results in the least possible time and the least expenditure of energy as shown by retention and recall. Interest, attention, and fatigue of the pupils were observed. Twenty-four juniors or seniors in the McGuffey High School of Miami University were divided into three groups, and were required to study several lessons by the different methods. After

4. Wiley, W.H., "An Experimental Study of Methods in Teaching High School Chemistry", Journal of Educational Research, IX, (April, 1918), pp. 181-198.

each lesson, and also a month later, the pupils were required to write out what they knew of the lessons. The "text-book" method gave the best results for immediate recall, while the "lecture" method was least effective of all. ¹ Barnard reports that this study is of little value because the tests that were used in the experiment were not objective.

The "lecture-demonstration" method was compared with the ⁵ "individual laboratory" method by Cunningham in 1920. The experiment was made in order to see if the "individual laboratory" method was worth the time it takes, and whether as good results could be obtained by the other method. Twenty-five high school sophomores studying botany were divided into two equivalent groups based on ability, intelligence and previous school marks. The two groups studied thirteen experiments and were given tests immediately after they were performed. Cunningham concluded that time was saved by the "lecture-demonstration" method and that the "individual laboratory" method was superior in training for manipulation of apparatus and for obtaining exact results.

The "developmental" method (the experimental method applied orally in the class room), the "lecture" method, and the "text-book" method were compared with respect to immediate re-

5. Cunningham, H.A., "Individual Laboratory Work Versus Lecture Demonstration in High School Science", University of Illinois Bulletin, XVIII, (December, 1920) pp. 105-107.

call, retention, and the development of ability to answer thought questions by Hunter⁶ in 1922. Three classes in first year science were used in the investigations which were carried out in the DeWitt Clinton High School in New York City. Each class studied under each method each day, and took tests after each period of study. A test was given in each subject one week later in order to measure retention. Hunter reports that the "developmental" method was the best for retention, while the "lecture" method gave the best results for immediate recall.

Another part of the experiment attempted to determine whether the personal element of the teacher had any effect on the methods. The experiment was conducted with three other teachers and as nearly equivalent groups of pupils as possible. The results showed that the teachers who had been using some one of the methods, got the best results with that method.

In 1922, Webb⁷ reported that pupils with no laboratory experience showed no laboratory resourcefulness, and that males excelled females in laboratory work. He also stated that older pupils did no better work than younger ones.

In a rather poor study, Coopriider⁸, in 1922, found that

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6. Hunter, G.W., "An Experiment in the Use of Three Different Methods in the Classroom", School Science and Mathematics, XXII, pp. 875-890.
 7. Webb, H.A., "Testing Laboratory Resourcefulness", School Science and Mathematics, XXII, (Mar. 1922), pp. 259-267.
 8. Coopriider, J.L., "Oral Versus Written Instruction and Demonstration Versus Individual Work in High School Science", Masters' Thesis Abstracted in School Science and Mathematics, XXII, (December, 1922), pp. 838-841.

oral instructions were better than written ones, and that individual work with oral instructions was better than demonstration with oral instructions.

9

In 1923, Kiebler and Woody published a study of the "individual laboratory" and the "demonstration" methods. The subjects of the experiment were two physics classes equated on the basis of I.Q. The usual technique of experimentation was employed on fourteen heat experiments. The results of the group under the demonstration method were as good, if not better than those of the other group in all tests that were given. The investigator notes that even though the advantage in favor of the demonstration method is slight, it is very significant.

10

Coopriider, in 1923, published a study similar to the one he published in 1922. In this experiment he eliminated many of the faults of the first one. He attempted to find the relative retention value of four methods of teaching laboratory exercises in high school science--the individual with oral and with written instructions, and the demonstration with oral and with written instructions. The usual experimental technique was used on a sophomore class of sixty-eight pupils which was divided into four nearly equivalent groups. The tests used were quite objective. The results showed that demonstration work goes

9. Kiebler, E.W., "The Individual Laboratory Versus the Demonstration Methods of Teaching Physics", Journal of Educational Research, VII, (January, 1923), pp. 50-58.

10. Coopriider, J.L., "Laboratory Methods in High School Science", School Science and Mathematics, XXIII, (June, 1923) pp. 526-530.

best with oral instructions and that individual work is preferable to demonstration work.

11

Cunningham published another study of the "individual" versus the "demonstration" method in 1924. The purpose of the comparison was to determine which method was more efficient for immediate and delayed recall for dull and bright pupils. Cunningham carried two investigations which involved (1) two fairly equivalent groups in botany, equated on the basis of I.Q. and school grades, and (2) ten pairs of pupils. Thirteen laboratory exercises were studied and then written up at various intervals. The results showed that the "demonstration" method was better for immediate recall and that the "individual" method was better for delayed recall. For slower pupils, both methods were equally good.

The "demonstration", "individual", and "combination-demonstration-individual" methods in chemistry laboratory work were compared by Pruitt ¹² in 1925. Three groups of twenty pupils each, equated on the basis of I.Q., were used as subjects in the Great Falls High School, Montana. None of the methods proved to be superior for immediate recall, but the "individual" method was better than the "demonstration" method for retention.

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11. Cunningham, H.A., "Laboratory Methods in Natural Science Teaching", School Science and Mathematics, (June, 1924), pp. 709-804.
 12. Pruitt, C.M., "An Experiment on the Relative Efficiency of Methods of Conducting Chemistry Laboratory Work", M.A. Thesis, Bloomington, Indiana, University of Indiana, (1925)

Another study of the "individual laboratory" and the "lecture-demonstration" methods was published by Anibal¹³ in 1926. He found little difference between the two methods.

Coopri¹⁴der, in 1926, published a study of the relative effectiveness of "student" versus "teacher" demonstration methods. He equated four sections from a group of seventy-four pupils in biology on the basis of I.Q. The usual experimental procedure was used in doing eighteen laboratory experiments. A report was written by each pupil after the experiment. The results obtained showed that the superior students did fully as well as teachers in demonstration experiments before a class.

Nash and Phillips¹⁵, in 1927, published a study of the "individual", the "demonstration", and the "combined-individual-demonstration" methods with respect to learning of subject matter. Three second semester chemistry classes of fifteen pupils each, equated on the basis of I.Q., were used as subjects. The investigators concluded that the "demonstration" method was

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13. Anibal, F.G., "Comparative Effectiveness of the Lecture-Demonstration and Individual Laboratory Methods", Journal of Educational Research, XIII, (May 1926) pp. 355-365.
 14. Coopri¹⁴der, J.L., "Teacher versus Student Demonstration in High School Biology", School Science and Mathematics, XXVI, (February, 1926), pp. 147-155.
 15. Nash, H.B. and Phillips, M.J., "A Study of the Relative Value of Three Methods of Teaching High School Chemistry", Journal of Educational Research, XV, (May 1927) pp. 371-379.

superior to the others. However, they report that their conclusions should not be looked upon as conclusive because of the small number of subjects that they used in their experiment.

16

Johnson, in 1928, published a study of laboratory methods--comparing the "lecture-demonstration" method with the "group laboratory" method. Three biology classes of eleven members each, paired on the basis of I.Q., were used as subjects. The results showed that the "lecture-demonstration" method may be expected to yield equal, if not better results than the "laboratory" method.

17

In 1930, Walter published a study of an experiment with the "individual-no-manual" and the "demonstration" method. Pupils studying physics were divided into three sections, and each section did two experiments by each method. Walter found that the "individual-no-manual" method was best adapted for drill work, particularly where the pupils understood the problem involved before they did the exercise. The "demonstration" method was the better method where information was to be learned.

One of the most recently published investigations (1938) is the study of the "lecture-written-response" and the "indi-

16. Johnson, P.O., "A Comparison of the Lecture-Demonstration, Group Laboratory Experimentation and Individual Laboratory Experimentation Methods of Teaching High School Biology", Journal of Educational Research, XVIII, (Sept. 1928) pp. 103-111.

17. Walter, C.H., "The Individual Laboratory Method of Teaching Physics With No Printed Directions", School Science and Mathematics, XXX, (April, 1930) pp. 429-432.

vidual conference" methods by Mitchell¹⁸. Students, paired on the basis of "six-weeks' grade-point ratio, sex, and I.Q. percentile rating", were taught by the respective methods, and tested before and after the teaching with objective tests. All conditions in the experiment were well controlled. The results showed that the "individual conference" method was better than the other method. However the investigator remarks that this conclusion was reached on the conditions as they exist at Muskingum College, where the experiment was carried out, and that the method might not prove as successful under different circumstances.

There are many more studies of "laboratory" and "lecture" methods. All of them attack the educational problem with a slightly different point of view, and all of them produce results similar to those found in the described studies.

(2) Visual and oral methods--In 1922, Hunter¹⁹ published his work on the relative values of visual and oral instruction in demonstration and experimental work in biology. Two first term classes of "poor average mental ability" pupils were used in this experiment. The "visual aids" group omitted all dis-

18. Mitchell, R.H., "Laboratory Teaching in Geology", School Science and Mathematics, XXXVIII, (October 1938), pp. 786-788.

19. Hunter, G.W., "An Attempt to Determine the Relative Values of Visual and Oral Instruction in Demonstration and Experimental Work in Biology", School Science and Mathematics, XXII, (January 1922) pp. 22-29.

ussion and had all names and scientific terms written on the board. The "oral" group discussed problems and experiments and were questioned by the teacher. Both groups were tested each day with ten minute quizzes on the work of the preceding day. The "oral" method proved to be very helpful to the low mentality pupils, and the "visual" method did not give good results, particularly on tests involving comparisons and analysis. Barnard¹ says that the subjects in this experiment were not representative nor properly educated, and that therefore the results are of little value.

In 1922, Hunter²⁰ also published the results of his experiment to determine the relative values of the "oral demonstration" method and the "individual laboratory" method with respect to laboratory experimentation. The subjects in this experiment were the same as those he used in his previous experiment. Both groups were tested with the same test. The groups were rotated after a time. The "oral developmental" group did better work.

In 1929, Wood and Freeman²¹ published the results of a very extensive study to determine the effects of ten teaching films on seventh, eighth and ninth grade general science pupils, with respect to "ability to interpret experiences and to make

20. Hunter, G.W., "The Oral Versus the Laboratory Method", School Mathematics and Science, XXII, (January, 1922), pp. 29-32.

21. Wood, B.D. and Freeman, F.N., Motion Pictures in the Classroom.

inferences and judgments", and "to recall concrete objects and processes, and to abstract general facts". The only variable factor between the control and the experimental groups was that the experimental groups saw the ten films and the other did not. The subjects of the experiment were 3,265 pupils, who were divided into approximately equal groups and equated on the basis of I.Q. and knowledge of general science. Improvement was measured by the use of objective tests. In general, the "visual groups" gained more than the other groups. These results are very significant because the experimental groups were a little lower than the control groups in I.Q., school grades, and achievement, and had more uninterested pupils. This experiment shows the value of visual aids in teaching.

A report of a well controlled experiment on the value of sound films in general science was published by Rulon²² in 1933. Three ninth grade classes were the subjects of the experiment. The "ordinary", the "text-book", and the "text-book with sound motion pictures" methods were employed for thirty-two days on about 2000 pupils who were equated on the basis of I.Q., previous knowledge of science, and chronological age. Rulon composed a special text book and several objective examinations. Eight films were used in the experimental group. The results of the study are summarized as follows:

22. Rulon, Phillip J., The Sound Motion Picture in Science Teaching. pp. 56-57.

1. The use of talking motion pictures caused an increase of more than twenty per cent in the general achievement in general science in the experimental group.
2. The use of talking motion pictures caused an increase of more than thirty-five per cent in achievement on matters specifically treated by the films.
3. There is no evidence in this study that these increases were made at the expense of other educational values such as scientific thinking.²³

There are many more studies of visual aids which definitely indicate that visual aids have their place in the modern classroom. One of the most recent studies--and the last to be mentioned here--is that of Hall²⁴, published in 1936. The investigation was to determine whether classroom films were most effective when (1) the pupils were informed that they were to be tested on the material to be seen, (2) the pupils were not to be tested, or (3) the pupils could see the test which was to be given all during the showing of the film. The rotation method of experimentation was employed on three small classes and pre-tests and delayed tests were given. Hall concluded that the third method was best. He indicates, however, that the fact that he himself developed the method might have some influence on the result even though he made every effort to control all conditions.

23. Ibid. pp. 57.

24. Hall, B.J., "A Study of Three Methods of Teaching Science with Classroom Films", School Science and Mathematics, XXXVI, (December, 1936), pp. 968-973.

(3) Study methods--In 1909, Gilbert performed an experiment on methods of teaching zoology in the Academy of the University of Illinois. The experiment was a comparison of an economic and a scholastic approach to the study of animals. The subjects were two groups of pupils equated on the basis of age, sex, fathers' occupation, pupil's home occupation, and pupil's intended occupation. Both groups studied the same material for the same length of time and were tested with identical written examinations. The only variable was the method used in teaching the class. Gilbert concluded that there was a slight advantage in favor of the economic approach, but that the advantage was too small to warrant final conclusions from his work.

¹
Barnard considers Gilbert's work of little value because of the unsound techniques he used in equating and testing his subjects.

26

In 1923, Beauchamp made a very careful study of the relative efficiencies of "semi-directed" and "directed" study, in which he used two, twenty-six pupil eighth grade classes in the University of Chicago High School. The groups were equivalent with respect to age, native intelligence, rate of silent reading, and ability to interpret what is read. Six units of science

25. Gilbert, J.P., "An Experiment in Methods of Teaching Zoology", The Journal of Educational Psychology, I. (June, 1910) pp. 321-322.

26. Beauchamp, W.L., "A Preliminary Experimental Study of Techniques in the Mastery of Subject Matter in Elementary Physical Science", Supplementary Educational Monographs, 24, pp. 47-87.

were studied. In this work, Beauchamp carried out six separate studies:

- a. In order to find whether the "semi-directed" group or the "directed" group would be better in assimilating subject matter, he gave both groups objective tests. Results showed that one class assimilated the subject matter as well as the other.
- b. The "directed" study group was instructed to study each paragraph to get the main idea and the contributing ideas. The other group was given only general study directions. Again tests were given. The "directed" group showed greater ability in subject matter assimilation.
- c. The "directed" study group was given definite instructions on how to solve problems of the unit; the other group got only general directions. The results obtained showed that the "semi-directed" group was more efficient and that the "directed" group seemed to focus too much attention on detail and not enough on major relationships.
- d. The "directed" group was instructed to read all through a unit to get the general plan, and then to group the major facts around it. This group was found to assimilate subject matter better than the other group which did not receive these directions.
- e. The "directed" study group was given special instructions and practice in solving thought questions. This group with the special training showed better results.
- f. The "directed" study group was given special instructions on how to study. This group was then able to read with greater understanding, while the other group was able to read more rapidly.

¹
Barnard states that up to this time, "these studies are the best controlled learning studies that have been reported".

Another report on the influence of instruction and drill in paragraph summarizing was published by Persing ²⁷ in 1924.

27. Persing, K.M., "A Practice Study in Paragraph Summarizing in Chemistry", School Science and Mathematics, XXIV, (June, 1924) pp. 598-604.

Two classes in beginning chemistry, each containing twenty-three pupils, were used as subjects. Pretests were given, and after a period of instruction, the pupils were tested again. The results showed that the summarizing practice produced a decided improvement in assimilation of subject matter. ¹Bar-nard reports that these results are not reliable nor objective because of poor techniques and materials.

In 1927, Hurd ²⁸ published a study in which he found that there are no advantages in a "combined study and recitation" method over a method in which the pupils study outside of the regular class hours.

The results of an experiment with two plans of supervised study--the study precedes the recitation in one, and the recitation precedes the study in the other--were published by Douglas ²⁹ in 1928. Two ninth grade classes in the University of Oregon High School were equated for chronological age, I.Q., and scores on the Ruch-Popencoe General Science Test. The groups were rotated, well controlled and tested with objective tests. Douglas concluded that "neither sequence seems to be connected in general with the production of larger variations

28. Hurd, W.A., "Suggestion on the Evaluation of Teaching Procedures in High School Physics", School Science and Mathematics, XXVII, (May, 1927), pp. 220-226.

29. Douglas, H.R., "An Experimental Investigation of the Relative Effectiveness of Two Plans of Supervised Study", Journal of Educational Research, XVIII, (October, 1928), pp. 239-245.

of progress with one class than with the other".

In 1932, Robertson³⁰, published the results of a comparison of the "guidance outline" method and a "developmental discussion" method with respect to immediate and delayed recall in fifth grade general science at the Oxford School, Dearborn, Michigan. Sixty pupils were used as subjects; and the usual rotation procedure was employed. Measurements were made with objective tests. It was found that the "developmental discussion" had slight, but not statistically significant, results.

Barnard¹, himself, made a study of the relative effectiveness of a "teacher-prepared study guide" and a "student-developed study guide" method in the teaching of general science with respect to growth in scientific attitudes, ability to solve problems, and ability to apply generalizations. He used a maximum of sixty-eight pupils in four different high schools. The groups were equated on the basis of reading ability in science and on scores made on pretests on the material to be studied. The "student-developed study guide" group was given special instruction in making study guides for ten weeks before the experiment started. The other group was given a set of teacher-prepared study guide sheets. This group carried on class discussions for class work while the other group developed their guides. Identical tests were given to both groups. Barnard concluded that the "student-developed study guide" method has slight advan-

30. Robertson, M. L., "A Study of the Relative Effectiveness of Two Methods of Teaching Elementary Science", Science Education, XVI, (February, 1932), pp. 182-187.

tage over the "teacher-prepared study guide" method. The results, however, are not statistically significant. This experiment seems to have been well controlled, but the tests which were supposed to measure the described outcomes of teaching might just as readily have been used to measure subject matter assimilation.

Many more such investigations have been reported. Most of them show that the more progressive methods of study have some advantage over other methods.

(4) The use of drawings and laboratory reports--In 1916,
 31 Ayer carried out an experiment to determine the effects of representative drawing (very detailed and accurate), analytical drawing (sketches containing only the most important parts), and verbal description on laboratory practice in first year high school general science. He concluded that representative drawing wasted time and encouraged habits of copying, and that analytical drawings were ideal records of completed work and should be used whenever possible.

32

In 1928, Ballew published a report on the effectiveness of laboratory exercises, with and without drawings, on high school zoology. In the Austin High School, Chicago, two beginning classes were equated on the basis of I.Q., and were taught the material of fourteen experiments. The usual rotation

31. Ayer, C., The Psychology of Drawing with Special Reference to Laboratory Teaching, pp. 107-108.

32. Ballew, A.M., "A Comparative Study of the Effectiveness of Laboratory Exercises in High School Zoology", School Review, XXXVI, (April, 1928) pp. 284-295.

procedure was used. The results showed that drawings do not improve pupil response to tests. This experiment should prove of great interest to teachers who still require drawings.

In 1929, Moore, Dykehouse, and Curtis³³, in an experiment to determine the best way to report laboratory exercises in general science, found that a "diagram" method showed slight advantage over the "conventional" method. The experiment lasted over a period of fifteen weeks and included twenty-seven exercises. Two paired classes in different schools were used.

In 1928, Bail³⁴ reported an experiment which showed that the method used in the reporting of laboratory experiments is of little importance; the important factor is "how well it is recorded by whatever method is used". The experiment from which he obtained his data was well controlled and included the study of twenty-two experiments by three equated groups.

(5) Project methods--The results of a study to determine the relative effectiveness of the "project" and "non-project" methods with respect to pupil accomplishment and preference was published by Garber³⁵ in 1922. Two second term chemistry classes were taught by the two methods. The groups were equated on the

33. Moore, F.W., Dykehouse, C.J., and Curtis, F.D., "A Study of the Relative Effectiveness of Two Methods of Reporting Laboratory Exercises in General Science", Science Education, XIII, (May, 1929), pp. 229-235.

34. Bail, P.M., An Experimental Study of Methods of Recording High School Physics Experiments, M.A. Thesis, State University of Iowa, 1928.

35. Garber, Ellinor, "The Project Method in Teaching Chemistry", School Science and Mathematics, XXII, (Jan. 1922), pp. 71-73.

basis of I.Q. and all tests used in the experiment were objective. The "project" method group produced better results, and most of the pupils favored that method. Barnard¹ reports that the value of this experiment is lost in that the investigator neglected to define the "project" method.

36

Watkins, in 1923, published the results of an experiment to determine whether "project teaching" was as good as teaching by "traditional" methods. He used twenty-five pupils of the University of Missouri High School who had been trained in the "project" method for the past three years. For comparison, Watkins chose ten first year science classes which were being instructed by "traditional" methods. All conditions except maturity were about the same. Several textbooks were analyzed and a test which measured assimilation of subject matter was constructed. Watkins determined the validity and reliability of the test. The results of the experiment showed that pupils trained by the "project" method do as well as those not so trained. If I.Q. is considered, the "project" group can be expected to do better work.

A report of an experiment in extensive reading in general science as a means of increasing knowledge of science fact and principle was published by Curtis³⁷ in 1924. There were three

36. Watkins, R.K., "The Technique and Value of Project Teaching in General Science", General Science Quarterly, VII, (Oct. 1923), pp. 235-256; VIII, (January, 1924) pp. 848-851.

37. Curtis, F.D., Extensive Reading of General Science As a Means of Increasing Knowledge of Scientific Facts and Principles, Contributions to Education, 163, Columbia University, 1924.

parts to the study:

- a. An attempt was made to determine the effect of the reading when it was given as part of an extra course program. Several science books were collected in a library and made available to forty-five eighth grade pupils in a New York High School. A seventh and a ninth grade class were used as a control. Equating was done on the basis of a "brightness quotient". All groups were tested with Dvorak, S-2 General Science Scale at the end of the experiment. The reading group proved to have gained months more than the other groups.
- b. An attempt was made to determine the effect of the reading when it was substituted for a part of the regular classwork. The same procedure was used. The experimental group gained six months more than the control groups.
- c. An attempt was made to determine the effect of the reading when it was given in addition to all the other classwork. The same procedure was used. This time the experimental group gained eight months more than the control groups.

These studies are valuable in that they establish the importance of reading materials in science classes.

38

Hurd published a study of a "topical" versus a "problem" method in the assimilation of subject matter in high school physics. In the North High School, Minneapolis, two groups of physics pupils, equated on the basis of I.Q., achievement, and industry, were used as subjects. One group studied topics, the other studied problems. At the beginning and at the end of the experiment, Hurd gave objective informational tests. The "topic" method produced better results.

38. Hurd, W.A., A Study of the Relative Value of the Topical Versus the Problem Method in the Acquisition of Information on the Subject of Heat in High School Physics, School of Education Bulletin, XXVIII, University of Minnesota, (1925) pp. 3-9.

Corbally , in 1930, published his findings in an experiment to determine the relative effectiveness of the "assignment-recitation" plan and the "unit" plan. Using four average intelligence general science classes of the Queen Anne High School in Seattle, he found such slight variations that he concluded that neither method was better than the other.

Several other investigators got results that indicated that "project" plans have little if any advantage over other methods, but most of the investigators urge the use of the "project" plans because pupils seem to prefer them.

40

(6) Freedom methods--In 1934, Bradbury reported the results of an experiment which was similar to the study reported in this thesis. Two ninth grade general science classes were equated on the basis of I.Q. and scores on the Dvorak General Science Scales. The general principles of the "freedom" method employed by Bradbury are similar to those presented in Chapter III, "The Experimental Method". The experimental group used a variety of texts, did much experimentation, used interest as a guide, stressed pupil importance, used much discussion, and allowed originality. The chief difference between this experiment and the one reported in this thesis is that the teacher took a less active part, allowing the pupils to "simply browse".

39. Corbally, J.E., "A Comparison of Two Methods of Teaching General Science", School Review, XXXVIII, (January, 1930), pp. 61-66.

40. Bradbury, B.S., A Pupil Initiated Course in General Science for a Slow Group, M.A. Thesis. Colorado State College of Education, 1935.

The rotation method of experimentation was used, and objective tests were used to measure gains. The experimental method proved to be better than the "ordinary" method of teaching.

The work of Davis⁴¹, Singleton⁴², and Bent⁴³ shows that the freedom methods caused pupils to do more work, allowed greater pleasure and satisfaction, contributed to character and personality development, and produced as good results as other formal methods. The "experimental" method developed by the investigator differs from the methods used by the previous workers in that it has definite organization in spite of its plasticity. Other than this, it incorporates what the others contain individually.

(7) Generalizations from the reported studies--Noll^{2b} summarizes science education research very briefly.

The conclusions of the entire study seem to be:

- a. that some time and money can be saved by lecture demonstrations, although just how much of a saving can be effected has never been carefully established;
- b. it has been shown rather clearly by a few investigations that individual laboratory work produces certain results in the pupil more efficiently and more permanently than the demonstration does;

41. Davis, J.S., An Experiment in Liberalizing Instruction in Chemistry, M.S. Thesis, University of Southern California, 1935.

42. Singleton, H.C., A Comparison in the Changes in Pupils' Character and Information Resulting from Instruction in General Science by the Activity Method versus the Traditional Recitation Method. M.A. Thesis, Pennsylvania State College, 1935.

43. Bent, R.K. "Comparative Effectiveness of a Freedom Method and a Conventional Method of Teaching High School General Science" School Science and Mathematics, XXXIII, (Oct. 1933), pp. 773-776.

2b. Noll, V.H., The Teaching of Science in Elementary and Secondary Schools, pp. 43-65.

- c. choice of which method to use depends on the total situation.

One is therefore forced to conclude that about all that can be done is to make some suggestions as to when each method may be used to advantage.

- a. Other things being equal, use lecture demonstration for the more difficult and more expensive experiments.
- b. Other things being equal, use the individual laboratory method for simple, short, and less expensive experiments.
- c. Require pupils to submit brief but carefully and accurately written reports of experiments.
- d. Recommend that pupils make simple, analytic drawings rather than representative ones.
- e. Use visual aids.
- f. Organize materials of instruction and present them by methods that encourage the pupil to a maximum of freedom and self-direction and that permit the fullest possible provision for individual differences.

Another review of experimental investigations in science education published by ²Duel in 1937, summarizes the work that had been done with laboratory and with lecture-demonstration methods. He includes most of the work already described, and several others; but his review is interesting because he has extracted the essence of method from all.

A number of investigations have been made with regard to the relative merits of the lecture-demonstration method and the individual laboratory method of instruction in secondary school science. Coopridge and Johnson compared these methods with classes in biology; Cunningham with classes in botany; Anibal, Carpenter, Horton, Knox, Nash, Phillips, Pugh, and Wiley, with classes in chemistry; and Dyer, Phillips, Walter and Kiebler and Woody, with classes in physics.⁴⁴

44. Most of these experiments have already been described. Complete reference for those omitted can be found by reading the reference cited in footnote 2.

In general, the method of conducting these investigations was as follows: On the basis of intelligence tests or such tests and the students' previous grades in science, the students to be instructed were divided into two groups of approximately equal ability. One group was then taught by the lecture-demonstration method and the other by the individual laboratory method. Carpenter, Dyer, Horton, and Johnson used the rotation procedure; that is the same students were taught one exercise or set of exercises by the laboratory method. This method of procedure made it possible for them to compare, not only the achievement of two groups taught by two different methods, but also the achievement of the same group taught by two different methods.

At the close of each study, these two groups were given identical tests, and upon the basis of these tests, the comparative efficiency of the two methods was determined. Usually the groups were tested a second time after a considerable interval; this interval varied in the several studies. The purpose of these delayed tests was to determine the relative efficiency of the two methods in terms of the knowledge retained after the interval.²

2b

As to final conclusions, Duel thinks very much as does Noll, whose conclusions have been quoted previously.

There can be little doubt, after reading all these investigations, that secondary school science can be taught in several different ways. The method that seems to have slight advantage over others is the lecture-demonstration method. But by no means, let it be assumed that this or any other method is presented as a panacea for educational ills.

It is the purpose of this investigation to compare the effectiveness of the "lecture-demonstration" method with a method constructed of the best elements of many others, in the teaching of general science.

THE EXPERIMENTAL METHOD

CHAPTER III

THE EXPERIMENTAL METHOD

Since the method of teaching science that is used in this experiment is somewhat of an innovation, it was considered advisable to describe it in some detail before summarizing the data of the experiment. The description is given in this chapter.

The "experimental" method used in this investigation is composed of many features found in other methods that are being used in high schools today. These features were selected from several methods, but no definite citations can be made because almost all ideas used were given different form and application.¹

It is impossible to clearly define the "experimental" method in one or two paragraphs; yet the method is not complex. The following outline is presented in order to summarize the most important features and to show the flexibility of the method.

(1) Outline of salient features--

- I. The instructor restrains himself from the tendency to monopolize the class discussion.
- II. The instructor trains his class in the proper "etiquette" of procedure.
 - A. One person speaks at a time.
 - B. Each person must be given ample opportunity to finish what he has to say.
 - C. Pupils must address themselves to the class and not to the teacher.
 - D. Any and all pupils of the class can and should take part in an open discussion and criticism of class work.

1. The method that most nearly resembles the "experimental" method is described by Bradbury, B.S., A Pupils Initiated Course in General Science for a Slow Group., M.A. Thesis, Colorado State College of Education, 1935.

- E. The instructor does not allow bright pupils to monopolize the discussions.
 - 1. He plans special topics and questions for them.
 - 2. He utilizes them as questioners rather than tellers.
- F. The instructor does not allow any member of the class to become a laggard.
 - 1. This is best accomplished by the instructor calling by name those pupils he wants to start a discussion on a new problem.
 - a. The experience of facing a group of inquisitive class mates soon brings about some desired activity. This might also involve some tactful prodding.
- G. Pupils must be made to realize that time is available only for pertinent material.
 - 1. The instructor exercises great care in allowing digressions.
 - a. If the interest of the class definitely swings in some other direction than that which was planned, and if this new interest is part of the future job of the class, and therefore worth while, the teacher should let the class go.
 - 2. Care, tact, and firmness are necessary.
- H. The instructor must allow no puerile controversy in class.
 - 1. He seeks and encourages expression of difference of opinion where such is possible, but he must allow no "squabbling".

III. The instructor allows a great amount of freedom in class and class assignments. Upon this depends the success of the entire plan.

- A. He exerts great care that too much freedom is not given.
- B. He does not allow the freedom that is given to be abused.
- C. He encourages originality in the creation of experiments and apparatus, and keeping of notebooks.
- D. He encourages much outside work--pictures, magazine articles, books, etc.
- E. Individual conferences should be held quite often.

- IV. The instructor must be able to efficiently direct classroom procedure by raising, defining, and modifying questions and problems, and yet not become too prominent.
- A. This involves careful day by day planning.
 1. What problems should the class be led into considering?
 2. How can the class be made to best consider all angles both for present and future purposes?
- V. The members of the class should be organized into two teams--one to test the ability of the other.
- A. This should be a standing assignment: "Make a list of twenty-five (or so) of True-False, Fill-in, or short answer questions as you read material in your texts and outside work".
 - B. When each member of the class has several questions, a review should be held in the form of a spelling bee.
 1. Rules: (any others that would work better in particular situations can be made).
 - a. The teacher is judge of all questions and answers.
 - b. A questioner can call upon any member of the opposing team.
 - (1) Care must be taken that the duller pupils are not over-worked.
 - (2) The questioning should be well distributed.
 - c. If themember of the team that was questioned cannot answer, then the questioner calls upon some member of his own team to do so.
 - (1) A correct response means a point for the questioning team.
 - (2) An incorrect response means no score.
 - d. All questions that are brought up should be answered before they are left.
 - C. A suitable reward should be given to the winning team at the end of a round.
 1. Each round should end with the end of a unit.
 - a. This to allow renewed enthusiasm in the losing team.

- D. This procedure is intended for review purposes, and must not be overworked.
1. Too much use of these science bees would defeat their purpose in that their novelty and interest would wear away.
- VI. The instructor always keeps in sight the general and specific objectives of the course as outlined on the course of study.

A description of the teachers activity during a typical class hour might give even a better understanding of the "experimental" method.

(2) The teachers activity--

- I. The teacher spends the first part of the period in "lecture-demonstrating" new material.
 - A. He emphasizes important ideas and principles, and presents material that the pupils might not get on their own.
 - B. He makes the assignment for the next day.
 1. He asks pupils to outline all work, both in texts and outside reading.
 - a. This should not be required.
 2. He asks all pupils to make a list of questions for the science bees.

- II. Before class the teacher outlines, briefly, on the blackboard, the specific objectives to be considered that day. Planning more than just enough is wise.
 - A. He lists several of the most important ideas in a word or two.
 1. Example: In the study of engines--

Engines--						
Steam--	construction--	operation--	principles			
Gas --	"	"	--	"	--	"
Diesel-	"	"	--	"	--	"

- III. The instructor gives short objective quizzes, about ten minutes in length, covering the work completed during the previous days' work. Overuse of this is not to be feared.
 - A. These quizzes are best given during the first ten minutes of the period because they can then serve as a means of review.

- IV. During the second part of the period (working under a variable time arrangement) the teacher joins the class and calls on some pupil to start a discussion by telling the class all that he can about any one idea listed on the board.

- A. The pupil goes to the front of the room and tells what he knows.
- B. When he finishes speaking, he asks for additions and corrections.
 - 1. Outside work, personal experience, extended discussion should come out here, one pupil calling on another.
- C. The class should carry on as in B. when the end of one topic is reached.
- D. If the class is ready for a drill, the teacher conducts a science question bee rather than a discussion.
- E. One day each week should be set aside for reports and experiments.

- V. The teacher should keep two sets of marks.
 - A. One set is a record of the scores made on tests.
 - B. The other is a record of the teachers opinion of the pupils' performance during the class discussions.
 - C. One set can either raise or lower the other.
 - D. The process of keeping these marks is easily controlled by using two colors in one marking book.

VI. Adaptation of all procedures to the teachers best convenience is of primary importance.

As can easily be seen, the method is constructed to appeal to the interest of the pupil and to give him a great amount of freedom in carrying out his work.

(3) General Comments--The pupil reaction to the "experimental" method was carefully observed during the investigation. Nothing unusual appeared in the performance of Class A, the control group, during the first six weeks because the pupils had been studying general science under the same teacher by the "lecture-demonstration" method for the previous three months. But Class B, the experimental group, brought up some problems. Many of the pupils took advantage of the new freedom which was given to them by doing little or no work for class preparation and were therefore unable to intelligently participate in the class discussions. The difficulty was that the pu-

pils did not know how to use their freedom. Frequently, pupils asked for specific, required assignments because they wanted to know what they had to do. In such cases the teacher described exactly what would be discussed during the next period and suggested that the pupils look up some material in the books listed on the bibliography sheets. During the first two weeks of the experiment, this assignment meant practically nothing. All this meant that the teacher had to do more work. However, the problem was rather easily solved by three factors of the "experimental" method:

1. the short quizzes,
2. the general science question bees, and
3. the pupil-controlled class discussions.

It at once becomes evident that the pupils did not have as much freedom as they might think they had. The quizzes served as a potent material incentive to study; the desire to participate in general science question bees led to a careful reading and fact hunting; and the fear of appearing stupid or dull in the class discussions--which were, to all appearances, pupil-controlled--meant preliminary preparation. The pupil's freedom was really freedom in the amount of study beyond a certain limit.

The introduction of the science units required more "lecture-demonstrating" time than was intended. The reason lay in the fact that the pupils had to learn a little about the subject before they could pick up any interests or do very much on their own. But, the amount of time required for this decreased daily

as the store of information increased.

And as the pupils' store of information increased, the class discussions became more and more worthwhile and interesting. The problem of getting the pupils to actively participate was solved by letting "stumped" pupils call on their classmates for aid. Many of the pupils called on in this way told of personal experiences with the subject under discussion; other pupils asked questions--some good, some bad--concerning the things they did not believe nor understand. Neither sheer curiosity nor a genuine desire to know was always the motive that prompted questions. Many times pupils asked a question just "to see if Johnny knew the answer". The friendly rivalry that developed between members of the class became very noticeable when individuals almost invariably called upon certain classmates. All this led to a desired end in that pupils studied harder in order to be able to answer questions when the opportunity came.

At irregular intervals, general science question bees were held. Two standing teams were organized, and the game was conducted as described in the "experimental" method outline. Several of the pupils took advantage of the science library and brought in many questions which they found in books other than their texts. Many such questions were objected to as in this typical conversation.

Pupil 2: "That question isn't fair. We aren't supposed to know that."

Pupil 1: "Yes, we are. I found it in a science book."

Pupil 2: "It isn't in our book. I didn't see it."

Pupil 1: "That's right, it isn't in our book. I found it in another one."

Pupil 2: "Aw-w! You can't do that--"

Pupil 1: "Yes., you can."

The teacher quickly settled such controversies.

A little study of this brings to light three very important outcomes of the "experimental" method.

1. Some of the pupils were studying more than just one science book. Whether or not the motive was that of finding "trick" questions is of little significance because in his search the pupil came into contact with more material and thereby increased the possibilities of finding new interests.

2. Some of the pupils who were not doing very much outside reading, were studying their texts so closely that they could recognize whether or not their text contained the answer to the question they were asked.

3. Many pupils, in most probability motivated by revenge, began to study more out-of-class material.

The use of these general science question bees did have one detrimental effect. The pupils developed a tendency to over-emphasize minute details. One of the most striking examples of this took place when a pupil asked, "What is the melting point of tungsten?". The teacher did not recall the answer to this question, and did not feel that the fact involved was worth remembering. When the teacher eliminated the question, both teams objected very much. It seems that everyone knew the answer. This difficulty was partially overcome by ruling out such over-

technical questions and by continually asking the class to emphasize the more important things.

On the whole, these science bees were very popular and successful. They served to motivate the pupils to study and review. In the opinion of both the teacher who taught the groups and the investigator, the science bee was one of the most effective and successful parts of the "experimental" method.

Nothing unusual developed in the pupil reports, experiments, and other outside work.

STATEMENT OF PROBLEM AND SUMMARY OF PROCEDURE

CHAPTER IV

STATEMENT OF PROBLEM AND SUMMARY OF PROCEDURE

This thesis is a report of an investigation of the relative effectiveness of the "lecture-demonstration" and the "experimental" methods in the teaching of general science.

(1) The problem--The study is concerned only with the question, "Will pupils studying first year high school general science assimilate more subject matter when studying under the "lecture-demonstration" method than under the "experimental" method?". (See Chapter III).

(2) The subject--Fifty-six general science pupils at the Amherst High School, Amherst, Massachusetts, were used as subjects in this study. The pupils in this group were typical of the high school, but they were a "selected" group in that all of them scored as high as the average high school freshman (ninth grade) on the Haggerty Reading Examination¹. All of the pupils lived either in the town of Amherst or on farms on the outskirts of the town. They were constantly exposed to more than the usual "academic and intellectual" activities in that two colleges are located in Amherst².

Amherst, located in the Connecticut Valley, is essentially a residential town, has little or no industrial interests, and serves a predominantly agricultural area.

(3) The materials--Several tests and scales were used in this study:

a. Intelligence quotients were determined from scores

1. Haggerty, M.E. and L.C., Haggerty Reading Examinations Sigma 3, Form A. Yonkers-on-Hudson, N.Y. World Book Company.

2. Amherst College and Massachusetts State College.

made on the "Otis Quick-Scoring Mental Ability Tests", Gamma
 3a Test, Form A . The coefficient of correlation of this test
 is .86; and it is considered to be quite valid by its authors.

b. The "Dvorak General Science Scales", Forms T-2 and
 3 S-2 , were used to measure general science achievement. These
 scales, containing several items of the Ruch-Popence General
 4 Science Test , were constructed on the basis of scores made by
 10,000 pupils in twenty-two large, medium, and small high
 schools. Both forms are of equal difficulty.

5 c. A long objective test was constructed by the investi-
 gator for the purpose of measuring assimilation of subject mat-
 ter studied during the experiment. The test consisted of one-
 hundred True-False, forty Fill-in, twenty-eight matching ques-
 tions, and twenty problems. The scores on even-numbered ques-
 tions, when correlated with the scores on odd-numbered ones,
 produced a coefficient of correlation of .876, with a P.E. of
 .023, calculated from the formulae

3a. Otis, Arthur S., Otis Quick-Scoring Mental Ability Tests;
 Form A, Yonkers-on-Hudson, New York, World Book Company.

3. Dvorak, August, General Science Scales, Forms T-2 and S-2,
 Bloomington, Illinois, Public School Publishing Co., 1924.

4. In the introductory pamphlet of Dvorak "General Science
 Scales", Ibid.

5. This examination will be referred to as the "Gruner Science
 Test" whenever mention is made of it in this report.

$$r = \frac{\frac{\sum xy}{N} - c_x c_y}{\sigma_x \cdot \sigma_y} \quad 6$$

$$P.E. = \frac{\pm .6745 (1-r^2)}{\sqrt{N}} \quad 7$$

Where r = coefficient of correlation, N = number of pupils, $\sum xy$ = sum of the products of the deviations from the xy axis, c_x and c_y = the correction for x and y axes, and σ_x and σ_y are standard deviations of the scores on the x and y axes.

The self-correction of the test was .934, as calculated from Spearman-Brown Prophecy Formula,⁸

$$r_{\text{self}} = \frac{N \cdot r}{1 + (N-1)r}$$

Where N = the number of times the test is given, and r = the self-correlation of the two parts of the test.

where r equals the coefficient of the odd and even numbered questions, and N equals two, the number of times the examination would theoretically have been given to get the correlation. The index of reliability of the test was .966, calculated from the formula⁹.

$$\text{Index of Reliability} = \sqrt{r_{\text{self}}}$$

A copy of the test is included in Appendix I.

d. Three major science units were outlined, and lists of "Suggested Teacher" and "Suggested Pupil" activity was prepared as guides for the teacher who taught the classes. These

6. McCall, William L., Measurement, pp. 527-530. This formula is here presented in a slightly different form in order to be consistent with letters used in formulae which follow.

7. Ibid.

8. Ibid. See Appendix III for Calculations.

9. Ibid.

units were:

- I. Power to do things--Machines,
- II. Heat,
- III. Sound.

The unit outlines, the teacher guide lists, and the references from which they were drawn, are included in Appendix II. Eleven General Science Texts were used in constructing these outlines.

e. In order to measure delayed recall, the investigator constructed two tests of twenty questions each. The questions, taken from the "Gruner Science Test" mentioned previously, were selected with emphasis on principles which the pupils were expected to retain. The first test contained questions on material which the students studied during the first stage of the experiment; and the second test contained questions on material studied during the second stage of the experiment. Each test contained fifteen True-False questions and five Fill-ins. The classes were not warned that they were to be quizzed. (See Appendix I.C.).

f. A questionnaire was constructed by the investigator in order to ascertain which of the methods the pupils preferred. The questionnaire contained forty questions, but all of them centered around but one--"Which method did you like better?". A copy of the questionnaire is included in Appendix IV.

g. Several short, objective quizzes on material studied during the previous day were used to measure immediate recall.

Samples of these quizzes are included in Appendix Ib.

(4) The procedure--The following steps were taken in the experiment:

a. Pairing--In order to obtain two equivalent groups, the fifty-six first year science pupils were paired on the bases of:

1. I.Q.--as determined by the "Otis Quick-Scoring Mental Ability Test",^{3a}
2. General Science knowledge--as determined by the "Dvorak General Science Scales"³
3. Knowledge of the units to be studied--as determined by the "Gruner Science Test",
4. Chronological age, and
5. Sex.

b. Pretests--The scores made on the Dvorak and the Gruner tests were used as pretest scores, and may be interpreted as the zero point of the experiment. The Dvorak Test and the True-False section of the Gruner Test were corrected and scored on the basis of the formula¹⁰

$$\text{Score} = \text{Number right} - \frac{\text{Number wrong}}{\text{Number of choices} - 1}$$

in order to eliminate the error caused by guessing.

c. Carry out the first section of experiment--then measure effects--The experiment was run for six weeks. Group A was the control group and was taught by the "lecture-demonstration" method; Group B was the experimental group and was instructed by the "experimental" method. At the end of the six week period, the Dvorak and Gruner tests were given to the pupils.

10. Greene, H.A. and Jorgensen, A.N., Use and Interpretation of High School Scores, Longmans Green and Company, (1937) p. 86.

d. Carry out the second section of the experiment--then measure the effects--The groups were rotated, that is Group B became the control group and Group A became the experimental one, and the experiment continued for six more school weeks. At the end of this time, the Dvorak and Gruner tests were given again. Since two forms of the Dvorak test were available, both were used--T-2 at the beginning and end of the experiment and Form S-2 at the rotation point.

e. Quizzes--Several identical, short quizzes were given to both classes at irregular intervals to determine immediate recall. Four were used during the first part of the experiment, and six during the second part.

f. Statistical treatment of results--Because none of the pairs of pupils were exactly equivalent at the start of the experiment, and because they were farther apart at the rotation point, individual gains from the pretest to the half-way test and from the half-way test to the final test were calculated, tabulated, and statistically treated to determine (1) means, M (2) standard deviations, S.D. (3) standard error of the means, S.E._m (4) standard error of the difference between two means, S.E._d and (5) critical ratios, C.R. The following formulae were used in the calculations:

$$(1) M = M_1 + \frac{(\sum fd)i}{N}$$

11. Tiegs, E.W., Tests and Measurements for Teachers, Boston, Houghton Mifflin Co., (1931) p. 234.

$$(2) \quad S.D. = \left(\frac{\sum f d^2}{N} - \left(\frac{\sum f d}{N} \right)^2 \right)^{1/2}$$

$$(3) \quad S.E._m = \frac{S.D.}{\sqrt{N}}$$

$$(4) \quad S.E._d = \sqrt{(S.E._{m1})^2 + (S.E._{m2})^2}$$

$$(5) \quad \text{Critical Ratio} = \frac{\text{Difference between means}}{S.E._d}$$

Where i = interval between scatter groups,
 N = number of pupils and
 $\sum f d$ = sum of the products of the frequency by the deviation of each group from the chosen mean.

Statisticians say that in order to be sure that there is a real difference between two groups, the critical ratio must equal at least 3.0. The results of the calculations are explained and summarized in Chapter V.

g. The questionnaire--At the end of the experiment, the teaching methods were explained to the pupils. A questionnaire was then given them in order to determine which of the two methods they preferred. The questionnaire, constructed by the investigator, contained forty questions, several of which were actual repeats. All of the questions centered around the one major question, "Which of the methods do you prefer?". In order to get the pupils true opinion, the investigator required that no pupil sign his paper.

(5) Analysis of the control--By means of the agents described under "Pairing", it was possible to obtain twenty-six pairs of pupils; but before the end of the experiment, it was necessary to eliminate two pairs because of absence and failure to make-up work. The results of the pairing and grouping are summarized in Table I.

TABLE I

COMPARISON OF GROUP A AND GROUP B WITH RESPECT TO INTELLIGENCE QUOTIENT, CHRONOLOGICAL AGE, ACHIEVEMENT ON THE "DVORAK GENERAL SCIENCE SCALES" AND "GRUNER SCIENCE TEST" MEANS AND STANDARD DEVIATIONS

	Class A	Class B	Difference A B
I.Q.	102.6 ± 12.3	102.0 ± 10.6	+ .6
C.A.	14-6 ± 9.2	14-5 ± 8.0	+ 1 mo.
Dvorak	23.8 ± 12.5	23.1 ± 8.9	+ .7
Gruner	25.5 ± 17.2	25.5 ± 15.2	± 0

It will be noted in this table that Class A and Class B are almost equivalent, but that in all cases but the "Gruner Science Test" Class A has a slight advantage. A study of the standard deviations shows that Class A is the more variable group.

Both of the groups were taught by the same teacher for a fifty minute period five days a week for twelve school weeks. Class A met during the first period, Class B during the second period of a six period school day. The teacher of the groups was supplied with outlines and guides. He studied these and discussed them with the investigator until he clearly understood the experimental method. The control of this experiment appears to be sufficiently accurate so that one could state that the differences in achievement that might appear between the groups would be due to the single variable--method.

SUMMARY OF DATA

CHAPTER V

SUMMARY OF DATA

In order to determine the relative effectiveness of the "lecture-demonstration" and the "experimental" methods, two equivalent groups were instructed by both of the methods in successive stages of an experiment. The pupils were then tested with the various tests described under "The materials" in Chapter IV. The pupils' scores were obtained, gains for both stages of the experiment were calculated, tabulated, and statistically treated to determine whether or not a real difference existed between the groups.

(1) Results from the "Dvorak General Science Scales"--

During the first stage of the experiment, Group A was the Control Group and Group B was the Experimental one. Table II shows the gains made by these groups. It will be noted that even though Class A has a slightly higher mean than Class B, Class B has a lower S.D. and, in general, has a lower frequency in the lower part of the table. The critical ratio¹ of the gains made by the groups is very small.

During the second stage of the experiment, Class A was the Experimental and Class B was the Control Group. Table II also shows the gains made by these groups during this part of the experiment. Again the Control Group shows a slightly higher mean than does the Experimental Group. An inconsistency appears in

1. The critical ratio is the numerical difference between two sets of scores divided by the S.E._d. The figure must be at least three to indicate a significant difference.

TABLE II

GAINS OBTAINED BY BOTH GROUPS ON THE "DVORAK GENERAL SCIENCE SCALES" FOR BOTH STAGES OF THE EXPERIMENT

Units Gained	First Stage		Second Stage	
	No. pupils in Group A	B	No. pupils in Group A	B
15	1		2	
12	1	1	1	
9	2	3		4
6	5	1	2	3
3	4	6	3	5
0	5	5	6	5
- 3	1	4	5	2
- 6	1	2	4	3
- 9	1	2		1
- 12	1		1	1
- 15	2			
Means	2.6	2.4	2.0	2.5
S.D.	7.7	5.5	6.5	5.9
S.E. _m	1.6	1.1	1.3	1.1
S.E. _d		1.9		1.7
C.R.		.1		.3

the S.D. in that the Experimental Group proves to be a little less variable than the Control. And, even though Class B has a slightly higher mean than Class A, Class A shows a higher frequency in the upper part of the table. Here again the critical ratio of the gains is very small.

(2) Results from the "Gruner Science Test"--During the first part of the experiment, Class A was the Control and Class B was the Experimental Group. Table III shows the gains made by the groups on the examination. The experimental Group showed a mean gain of 3.3 more than the Control Group. Very striking is the higher frequency of Class B in the upper part of the table, particularly since Class A shows no frequency there at all. However, the difference between the groups is so small in contrast to the S.E._d, that the critical ratio of the gains is insignificant.

During the second stage of the experiment, Class A was the Experimental and Class B was the Control Group. Here, again, the Experimental Group shows a mean gain of 6.4 higher than the mean gain of the Control Group. And consistent with the results of the first stage of the experiment, Group A has a higher frequency in the upper part of the table. And, even though the critical ratio of the gain is much larger than that of the first part of the experiment, it is still too small to be significant.

(3) Results from the delayed recall tests--During the first stage of the experiment, Class B was the Experimental Group. Table IV shows that this group produced a higher mean than the Control Group on a test covering material studied twelve weeks earlier. The difference between the groups, however, is too small to be significant.

Class B was the Experimental Group during the second stage of the experiment. And as on the previous test, the Experimental

TABLE III

GAINS OBTAINED BY BOTH GROUPS ON THE "GRUNER SCIENCE TEST" FOR BOTH STAGES OF THE EXPERIMENT

Units Gained	First Stage		Second Stage	
	No. pupils in Group A	B	No. pupils in Group A	B
80		1		
75		2		
70		2		
65	2	1		
60	3			
55		1		
50	2	1		
45	1	2		
40	2	4		
35	5	1	1	1
30	3	1	1	
25	1	1	2	
20	2	4	2	2
15	2	1	5	3
10		1	4	4
5			3	3
0	1		3	5
- 5			2	2
- 10		1	1	2
- 15				1
- 20				1
Means	39.8	43.1	13.5	7.1
S.D.	16.8	23.1	11.2	12.1
S.E.m	3.4	4.7	2.3	2.5
S.E.d		5.8		3.4
C.R.		.6		1.9

TABLE IV

SCORES OBTAINED BY BOTH GROUPS ON THE DELAYED RECALL TESTS COVERING THE MATERIAL OF BOTH STAGES OF THE EXPERIMENT

Scores	Test on Material of First Stage		Test on Material of Second Stage	
	No. pupils in Group A.	No. pupils in Group B	No. pupils in Group A	No. pupils in Group B
18			1	
16	2	1	4	5
14	2	3	6	3
12	4	4	3	1
10	2	6	1	4
8	6	6	3	5
6	4	2	3	4
4	3	2	3	1
2	0			1
0	1			
Mean	9.8	10.8	12.1	11.2
S.D.	4.0	3.0	4.4	4.2
S.E. _m	.8	.6	.9	.9
S.E. _d		1.0		1.3
C.R.		1.0		.7

Group produced a higher mean than the Control Group on a test on material studied six weeks earlier; but the difference between the two was not enough to be significant. It might be observed that, similar to the results of the other tests used in the experiment, the results shown in Table IV include more experimental than control pupils in the highest scores.

(4) Results from the quizzes--During the first part of the experiment, Class A was the Control and Class B was the Experimental Group. Table V shows that the mean scores made by the groups are consistent with the results obtained from the "Gruner Science Test"; the Experimental Group shows a higher mean than the Control Group. Similarly, the same group shows a higher frequency in the upper part of the table, and a lower frequency in the lower part of the table. The gain, however, is too small to allow a critical ratio that would have statistical significance.

The groups were rotated for the second stage of the experiment. Again the Experimental Group shows a higher mean than the Control. The high frequency of the Experimental Group in the upper part of the table is most striking when contrasted with the low frequency of the Control Group in this part of the table. The critical ratio approaches significance in this case, but is a little too small to allow one to say that a definite difference exists between the groups.

(5) Results from the questionnaire--On the whole, the pupils are quite definitely in favor of the "experimental" method. Table VI shows the percentage of pupils who favored the "experimental" method. The average percentage in favor of the "experimental" method is 65.3. This figure must not be looked upon as being of great significance because of the fact that the newness of the method and the very fact that the method was a departure from the ordinary would appeal to the pupils.

The answers to the questions that were repeated were not too consistent. Pupils answered "yes" to one question, and then "no"

TABLE V

SCORES OBTAINED BY BOTH GROUPS ON QUIZZES FOR BOTH STAGES OF THE EXPERIMENT

Scores	First Stage		Second Stage	
	No. pupils in Group A	B	No. pupils in Group A	B
54			1	
51			1	
48				
45			1	
42	1		2	
39	2	2	2	1
36	1	1	4	2
33		1	2	1
30	2	2		2
27	5	2	1	3
24	1	5	1	2
21	2	5	2	2
18	2	3	2	2
15	2	3	3	6
12	4		2	1
9				
6	1			2
Mean	24.8	25.9	31.5	23.4
S.D.	9.5	6.9	12.4	9.0
S.E. _m	2.0	1.4	2.5	1.8
S.E. _d		2.41		3.1
C.E.		.5		2.6

TABLE VI

PERCENTAGE OF PUPILS FAVORING THE "EXPERIMENTAL"
METHOD ON EACH OF THE FORTY QUESTIONS
ASKED ON THE QUESTIONNAIRE

Question number	%favoring the exp't'l method	Question number	%favoring the exp't'l method
1	68.5	21	47.2
2	-	22	75.4
3	57.7	23	31.4
4	37.0	24	61.6
5	-	25	71.6
6	88.5	26	62.2
7	86.8	27	52.8
8	55.6	28	74.1
9	85.2	29	67.9
10	69.8	30	56.6
11	-	31	60.4
12	-	32	60.4
13	76.9	33	75.4
14	76.9	34	78.8
15	-	35	46.0
16	59.2	36	58.5
17	85.2	37	35.3
18	66.1	38	75.0
19	47.1	39	75.0
20	69.2	40*	90.0

to the same question when it was repeated.

A summary of the reasons presented in the answers to question number forty, "Why do you like the "experimental" method?" includes:

- (1) "It is more fun".
- (2) "I learned things that were in other books which I had not read."
- (3) "It is more interesting."

* Question 40 was the most important question on the paper. The pupils were given a review of the pro and con aspects of the two methods by the previous questions. Question 40 asks which method they like and why.

- (4) "I liked it when the teacher called on one to discuss a certain article because I think I could answer better and get a better mark than on some hard test questions."
- (5) "It is more helpful and makes the work easier to understand."
- (6) "--because you have more of a chance to be called on to see what you know."
- (7) "It is more interesting to listen and to talk in a class discussion than to answer questions."
- (8) "The question bees were a lot of fun and you learn a lot from them."

The chief objections to the "experimental" method were:

- (1) "It is too easy."
- (2) "The assignments weren't definite."
- (3) "I had to do too much reading."
- (4) "I wasted a lot of time."
- (5) "I couldn't understand the work as well as when the teacher did all of the explaining."

These statements are typical of what the whole group had to say on the questionnaire, and are actual quotations from some of the papers. It will be noticed in Table VI that 90% of the pupils wanted to continue studying under the "experimental" method.

GENERAL SUMMARY, CONCLUSIONS AND
LIMITATIONS

CHAPTER VI

GENERAL SUMMARY, CONCLUSIONS, AND LIMITATIONS

(1) General Summary--This investigation is a study of the relative effectiveness of the "lecture-demonstration" and the "experimental" methods in the teaching of general science factual material. A study of the literature in science education failed to reveal any study comparing methods of this particular nature. The survey, however, showed that for many purposes the "lecture-demonstration" method was preferable to many other available methods, but that at best, it had its drawbacks. The "experimental" method was constructed by the investigator, who drew his ideas from several of the fairly successful contemporary methods. Three units of science were selected, carefully outlined, and organized from eleven standard text books. Several teacher-guide sheets were prepared, and a detailed outline of the "experimental" method was constructed. Fifty-six pupils of the Amherst High School were tested and paired on the basis of age, sex, I.Q., and achievement on the "Dvorak General Science Scales" and the "Gruner Science Test". The experiment was conducted for twelve weeks, the groups being rotated at the end of a six week period. Suitable objective tests were used to measure assimilation of subject matter. Scores and gains were calculated, tabulated, and statistically treated to determine whether or not a real difference existed between the two groups as taught by different methods.

(2) Conclusions--The results and the observations obtained from the described investigation make the following conclusions seem reasonable:

a. The "experimental" method has a slight, but not a statistically significant advantage over the "lecture-demonstration" method with respect to immediate recall.

b. The "experimental" method has a slight, but not a statistically reliable advantage over the "lecture-demonstration" method with respect to assimilation of subject matter as shown by delayed recall.

c. Fully as much, if not more measureable material can be taught by the "experimental" method as by the "lecture-demonstration" method.

d. The "experimental" method stimulates much more pupil interest and activity than does the "lecture-demonstration" method.

(3) Limitations--The limitations of this investigation are such that one cannot urge the unconditional adoption of this method in all schools. This investigation is based on only forty-eight pupils in a small high school; a new and previously untried test was used; only subject matter assimilation was measured--all these factors cause the investigator to recommend that the experiment be repeated on a larger scale, that more examinations be created, and that other than material outcomes be measured.

DISCUSSION AND RECOMMENDATIONS

CHAPTER VII

DISCUSSION AND RECOMMENDATIONS

(1) Discussion--As can easily be seen from the conclusions in the previous chapter, the "experimental" method offers little more material advantage than the "lecture-demonstration" method. However, material advantages are not the only things that are sought in teaching methods; in fact, they are but a small part of the aims of teaching. A study of the results of the questionnaire shows that many (90%) of the pupils favored the "experimental" method because it gave "something" to the course that it didn't have under the "lecture-demonstration" method. A study of the results of the tests used in the experiment shows that pupils learn little more by one method than by another. It might appear that no matter what method a diligent teacher might use, his pupils will absorb only a certain amount of information and no more. But, no matter how much measureable material the pupils learn, the teacher must be concerned with the many factors that contribute to the learning and its subsequent outcomes.

(2) Recommendations--This investigation has proved that the "experimental" method is at least as good as the "lecture-demonstration" method. And, it might be contended that the "experimental" method

- a. allows the pupils to get acquainted with science on a more personal and intimate basis,
- b. allows the pupils to talk over what they themselves see in science, and
- c. divorces the study of science from drudgery.

This, however, is opinion based on close observation and not on conclusion drawn from objective data. Therefore, it is recommended that the experiment be repeated for the purpose of measuring some of these less tangible outcomes.

APPENDICES:

- (1) Tests
- (2) Unit Outlines
- (3) The Questionnaire
- (4) Calculations of the Reliability
of the "Gruner Science Test".
- (5) Sample Calculations of Mean, Stand-
ard Deviation, etc.

APPENDIX I

- A. The Gruner Science Test
- B. Sample Quizzes
- C. Delayed Recall Tests.

A. The Gruner Science Test:-

SECTION I

Mark all statements which are true with +. Mark false statements with -. Do not guess.

A. Energy and Work.

- _____ 1. Wind blowing against the side of a house is doing work.
- _____ 2. A book lying on a table has potential energy.
- _____ 3. Kinetic energy cannot be converted into potential energy.
- _____ 4. Potential energy is stored up in a body as it is being lifted.
- _____ 5. Energy cannot be destroyed.
- _____ 6. Energy is the capacity to do work.
- _____ 7. Work always implies motion.
- _____ 8. The higher up a body is, the more potential energy it has.
- _____ 9. The columns supporting a building are doing work.
- _____ 10. The unit of work is "Horse Power".
- _____ 11. One H.P. the amount of work done by a horse in lifting one pound one foot.
- _____ 12. 10 foot lbs. of work are done in lifting 20 lbs. 6 inches.
- _____ 13. H.P. work x distance.
- _____ 14. James Watt invented H.P.
- _____ 15. Horse Power involves time.
- _____ 16. Heat is a form of energy.
- _____ 17. "Perpetual motion" machines are energy saving devices.
- _____ 18. Inertia is the tendency of a body to remain as it is, either in motion or at rest.
- _____ 19. All forms of energy can be measured.
- _____ 20. The sun is the basic source of energy.
- _____ 21. The simplest machine is an inclined plane.
- _____ 22. A machine is a device for transforming and applying energy.
- _____ 23. There are three classes of levers.
- _____ 24. A wheelbarrow illustrates a second class lever.
- _____ 25. The shorter the resistance arm of a lever, the greater a weight can be lifted.
- _____ 26. A pair of shears for cutting tin should have long handles and short blades.
- _____ 27. Pulleys are modified levers.
- _____ 28. Energy is gained when a simple pulley is used in lifting a heavy weight.
- _____ 29. A combination of a movable pulley with a fixed pulley is called a "block and tackle".
- _____ 30. The longer the handle on a windlass, the greater the effort necessary to lift a weight.
- _____ 31. More energy is used up in lifting a 300 lb. weight by hand than by means of a pulley.

32. Efficiency (output input) $\times 100$.
33. Resistance to motion is called friction.
34. Rolling friction is greater than sliding friction.
35. Skidding is caused by low friction.
36. Oil reduces friction.
37. The greater the weight, the smaller the inertia of a body.
38. The mechanical advantage of the inclined plane the length of the inclined plane \times its height.
39. A wedge changes the direction of the force applied to it.
40. The finer a thread of a screw, the smaller the mechanical advantage.
41. The greater the friction a machine has to overcome, the greater the efficiency of the machine.
42. Energy of steam or running water is converted into electric energy by means of turbines.
43. Gasoline forms an explosive mixture with air.
44. A gasoline engine loses power if the spark comes too late.
45. Gasoline engines are four-cycle engines.
46. Engines which force fuel oil into hot air are called Diesel engines.
47. All the cylinders of a gas engine fire at once.
48. Explosions create large volumes of gases.
49. Transportation is one of the most important contemporary industries.
50. Roads have curved surfaces to allow for contraction in winter.
51. Steam locomotives are good hill climbers.
52. Heat travels in waves.
53. Heat cannot be reflected.
54. Heat is a form of energy.
55. White clothing absorbs more heat than dark clothing.
56. Compound bars are used in thermostats.
57. Water is not a good substance to use in a thermometer.
58. $1\text{ C. } = 5/9\text{ F.}$
59. The formula for converting C.° to F.° is $\text{F. } = 5/9\text{ C. } - 32$.
60. Absolute zero has been reached.
61. Solids expand on heating.
62. Gases contract on heating.
63. Heat is the same as temperature.
64. When water freezes it gives up heat.
65. Water freezes at 32°C.
66. Heat has weight.
67. A calorie is the same as a B.T.U.
68. Conduction of heat is the passing along of molecular motion from one group of molecules to another.
69. Cold air rises.
70. Air is a good heat insulator.
71. Steam is hotter than boiling water.
72. It is a good idea to wrap ice in paper before putting it in an ice chest.

- _____ 73. A substance cannot be hotter than 212° F.
- _____ 74. Metals are poor conductors of heat.
- _____ 75. The electric refrigerator depends on the principle of "heat of fusion".
- _____ 76. Water is a good conductor of heat.
- _____ 77. Sound is energy.
- _____ 78. Air is a better conductor of sound than water.
- _____ 79. Vibrations produce sound.
- _____ 80. Wood and metals cannot carry sound.
- _____ 81. Echoes are caused by the absorption of sound.
- _____ 82. A Fathometer is an instrument for measuring sound intensity.
- _____ 83. Curtains are hung at the back of auditoriums to reflect sound.
- _____ 84. Increase of tension of a vibrating string raises the pitch of the sound produced by it.
- _____ 85. The pitch of a wire depends upon the diameter of the wire.
- _____ 86. The length of a wire has no effect on the pitch of the sound produced by it.
- _____ 87. The pitch of a sound depends on the number of vibrations per second.
- _____ 88. Music and noise are the same thing.
- _____ 89. Sound is the sensation that arises when impulses from nerve fibers reach the brain.
- _____ 90. The larynx is commonly called the "voice box".
- _____ 91. Sound produced by a phonograph is caused by the vibration of a diaphragm.
- _____ 92. Sound cannot be produced by vibrating columns of air.
- _____ 93. The grooves on a phonograph record are smooth.
- _____ 94. Sound travels well through loosely woven fabric.
- _____ 95. A compound note is a fundamental note.
- _____ 96. A sounding tuning-fork can make another tuning-fork of different pitch vibrate.
- _____ 97. Sound is not conducted through a vacuum.
- _____ 98. A large drum produces a note with a higher pitch than the note produced by a small drum.
- _____ 99. Sound waves tend to travel outward in all directions from the source.
- _____ 100. Sound travels through air at the rate of 186,000 miles per minutes.

SECTION II

Fill in the blanks.

1-6. The six simple machines are:

Machines

- | | | |
|------|---|-----|
| 1. | _____ | 1. |
| 2. | _____ | 2. |
| 3. | _____ | 3. |
| 4. | _____ | 4. |
| 5. | _____ | 5. |
| 6. | _____ | 6. |
| 7-8. | Foot pounds _____ x _____. | 7. |
| 9. | One horse can raise _____ pounds 1 ft. in 1 minute. | 8. |
| 10. | The support on which a lever rests is called _____. | 9. |
| 11. | A crowbar is a lever of the _____ class. | 10. |
| 12. | A wheelbarrow is a lever of the _____ class. | 11. |
| 13. | Resistance to motion is called _____. | 12. |
| 14. | The tendency to remain "as is" is called _____. | 13. |
| 15. | Screws are really modified _____. | 14. |
| 16. | The ratio between resistance and effort is called _____. | 15. |
| 17. | A _____ controls the entrance and exit of steam in a steam engine. | 16. |
| 18. | A gasoline engine is driven by a series of _____. | 17. |
| 19. | The air and gas mixture used in a gasoline engine is prepared in a _____. | 18. |
| 20. | Steam engines depend upon the principle of _____. | 19. |
| | | 20. |

Directions. Fill in the blanks at the right hand side of the paper with the word or words omitted.

- | | | | |
|-----|--|-------|-----|
| 1. | The best color for absorbing heat is _____. | _____ | 1. |
| 2. | The distribution of heat by the circulation of air or water is called _____. | _____ | 2. |
| 3. | Heat travels from the sun to the earth by a method called _____. | _____ | 3. |
| 4. | Heat travels from the inside of a radiator to the outside by a method called _____. | _____ | 4. |
| 5. | The amount of heat necessary to raise the temperature of one gram of water 1°C. is called _____. | _____ | 5. |
| 6. | The source of all heat is _____. | _____ | 6. |
| 7. | Of the three substances, wood, copper, and porcelain, _____ is the best heat conductor. | _____ | 7. |
| 10. | Three types of thermometer scales are _____. | _____ | 8. |
| | | _____ | 9. |
| | | _____ | 10. |
| 11. | Sound is caused by _____. | _____ | 11. |

12. Sound waves travel through air at a rate of _____ ft. per second. 12.
13. Echoes are caused by _____ of sound. 13.
14. The pitch of a wire varies (3) _____ 14.
- _____ 15.
- _____ 16.
17. The sound produced when overtones do not harmonize with the fundamental note is called _____ 17.
18. The sound produced by a phonograph depends upon the vibration of the _____ 18.
19. Wind instruments depend upon principle of _____ 19.
20. An instrument used to measure the depth of the ocean is called _____ 20.

SECTION III

Problems.

1. How much work does a 150 lb. boy do in getting from the ground to the roof of a building 50 feet high?
_____ Ans.
2. The boy runs up the stairs at top speed and gets to the roof in 1 minute. What horse power does his action display?
_____ Ans.
3. A boy, weighing 100 lbs. is sitting on the end of a board which is 10 feet long. The board is resting on a sawhorse; the point of contact on the board is just 6 feet from the end where the boy is sitting. What weight must be placed at the other end to just balance the boy?
_____ Ans.
4. John wishes to lift a box weighing 300 lbs. He has one double pulley and one single pulley with which to work. What is the minimum force John must be able to exert in order to lift the box?
_____ Ans.
5. A man, by using a system of pulleys, can lift 1000 lbs. by exerting 250 lbs. of force. What is the mechanical advantage?
_____ Ans.
6. What is the efficiency of a machine that requires 500 ft. lbs. of available work to produce 400 ft. lbs. of usable work?
_____ Ans.

7. The handle of a windlass is 2 feet long. The radius of the cylinder is three inches. How much force is necessary to lift 800 lbs.?

_____ Ans.

8. A boy can exert 100 lbs. of force. He wants to lift a box, weighing 250 lbs. to a platform which is 2.5 ft. high. How long a board must be used in order to get the box onto the platform?

_____ Ans.

9. The handle of a screw jack is 5 feet long. The pitch of the screw is one-half inch. How much force will be produced if a force of 5 lbs. is exerted at the end of the handle?

_____ Ans.

10. In what class of levers is the mechanical advantage greatest?

_____ Ans.

Directions. In the following write the answer in the blank at the right.

- | | | | | | | |
|-----|--|---------------|---------------------|-------|-------|----|
| 1. | 40°C. | $\frac{?}{?}$ | $^{\circ}\text{F.}$ | _____ | 1. | |
| 2. | 122°F | $\frac{?}{?}$ | $^{\circ}\text{C.}$ | _____ | 2. | |
| 3. | How many pounds of ordinary coal are necessary to raise the temperature of 504 grams of water 2°C. ? | | | | _____ | 3. |
| 4. | Your mother wraps a cake of ice in newspaper before she puts it in the icebox. Is this good economy? | | | | _____ | 4. |
| 5. | A man wishes to install heating units in a very large house. What method of heating do you advise?
a) electrical b) steam c) hot water d) hot air | | | | _____ | 5. |
| 6. | We hear an echo 4 seconds after the original sound was produced. How far away is the reflecting wall? | | | | _____ | 6. |
| 7. | A musician wishes to make stringed instruments which will produce a shrill sound. What do you advise him to use?
a) a long thick string b) a short thick string
c) a long thin string d) a short thin string | | | | _____ | 7. |
| 8. | The manager of a theatre finds that echoes make distinct hearing difficult. What do you advise him to do?
a) open windows b) rebuild the theatre c) hang curtains along the back of the hall d) put carpets on the floor e) ask the people to listen more closely | | | | _____ | 8. |
| 9. | A fathometer registers an elapse of 2.5 seconds between the start of a sound and its reception by a hydraphone. How deep is the ocean at that spot? | | | | _____ | 9. |
| 10. | Something is wrong with your phonograph. The motor seems to work well; but a scratching sound, or no sound at all is produced. What would you do? | | | | _____ | |

- a. take the motor apart for examination
- b. examine the diaphragm and needle
- c. try a different record
- d. call a repair man
- e. take the speaking horn off for examination

10.

Directions: In the column at left, mark the number of the term which has close connection with the phrases in the center list.

- | | |
|------------------------------------|--|
| <u>1.</u> absolute zero | a. capacity to do work |
| <u>2.</u> absorbtion | b. the push or pull which moves a body |
| <u>3.</u> B.T.U. | c. rate of doing work |
| <u>4.</u> calorie | d. energy of position |
| <u>5.</u> conduction | e. supports a lever |
| <u>6.</u> convection | f. ratio between resistance and effort |
| <u>7.</u> echo | g. resistance to motion |
| <u>8.</u> energy | h. weight x velocity |
| <u>9.</u> expansion | i. a molecular form of motion |
| <u>10.</u> force | j. tendency of a body at rest to remain at rest |
| <u>11.</u> friction | k. converts mechanical energy into electrical energy |
| <u>12.</u> fulcrum | l. principle of thermometers |
| <u>13.</u> gas engine | m. absence of all heat |
| <u>14.</u> heat | n. heat necessary to raise 1 gr. H ₂ O 1°C. |
| <u>15.</u> H.P. | o. heat of vaporization |
| <u>16.</u> inclined plane | p. evaporate readily at room temperature |
| <u>17.</u> inertia | q. passing of molecular motion from one group |
| <u>18.</u> mechanical advantage | r. produces sound |
| <u>19.</u> momentum | t. vibrations in halves |
| <u>20.</u> overtones | |
| <u>21.</u> potential | |
| <u>22.</u> power | |
| <u>23.</u> advantage latent | |
| <u>24.</u> turbine | |
| <u>25.</u> vibration | |
| <u>26.</u> volatile | |
| <u>27.</u> work | |
| <u>28.</u> zero degress centigrade | |

B. Sample Quizzes:

Indicate whether or not the following statements are true. Use a + if true, and a - if false.

1. Energy is the capacity to do work. _____
2. Work always involves motion. _____
3. Energy is the same power. _____
4. Energy and work are both measured in terms of foot-pounds. _____
5. The lever is the simplest machine. _____
6. A second class lever has the fulcrum placed between the effort and the resistance. _____
7. Effort \times Resistance equals effort distance times resistance distance. _____
8. A see-saw is an example of a first class lever. _____
9. A pulley system may be used to change the direction of a force. _____
10. Mechanical advantage is given by the ratio of effort to resistance. _____
11. The capstan is one form of the inclined plane. _____
12. The efficiency of a machine is affected by the amount of friction in it. _____
13. Machines may make use of friction, weight and inertia. _____
14. A man pushes with a force of 100 lbs. in order to roll a barrel up a plank into a truck which is three feet above the ground. He does 300 ft.-lbs. of work. _____
15. A 500 lb. weight has more inertia than a 5 lb. weight. _____

Sample Quizzes:

Indicate whether or not the following statements are true. Use a + if true, and a - if false.

1. In an automobile engine the carburetor mixes vaporized gas with air. _____
2. Diesel engines run on kerosene. _____
3. In a four cylinder auto engine, there are four valves. _____
4. The compression stroke of an engine comes just before the power stroke. _____
5. Burning takes place inside the auto cylinder. _____
6. Burning takes place inside the steam engine cylinder. _____
7. The cam shaft controls the action of the pistons. _____
8. The differential allows an auto to have different mechanical advantages. _____
9. The speed of a steam engine is controlled by a slide valve. _____
10. In a steam turbine, rectilinear motion is changed to circular motion. _____

C. Delayed Recall Tests:-

Section I

Directions:- Fill in the blanks with + or - to indicate True or False. Supply the missing word where necessary.

- _____ 1. A book lying on a table has potential energy.
- _____ 2. Heat is a form of energy.
- _____ 3. A pair of shears for cutting tin should have long handles and short blades.
- _____ 4. "Perpetual motion" machines are energy saving devices.
- _____ 5. There are three classes of levers.
- _____ 6. More energy is used up in lifting a 300-lb. weight by hand than by means of a pulley.
- _____ 7. Resistance to motion is called friction.
- _____ 8. The greater the weight, the smaller the inertia of a body.
- _____ 9. A wedge changes the direction of the force applied to it.
- _____ 10. All forms of energy can be measured.
- _____ 11. Potential energy can be converted into kinetic energy.
- _____ 12. The energy of steam or running water is converted into electrical energy by means of turbines.
- _____ 13. Roads have curved surfaces to allow for expansion in summer.
- _____ 14. A gasoline burning engine is called a diesel engine.
- _____ 15. 10 foot lbs. of work are done in lifting 20 lbs. 6 inches.
- _____ 16. The support on which a lever rests is called _____.
- _____ 17. A _____ controls the entrance and exit of steam in a steam engine.
- _____ 18. The ratio between resistance and effort is called _____.
- _____ 19. The air and gas mixture used in a gasoline engine is prepared in a _____.
- _____ 20. A boy weighs 100 lbs. He makes a see-saw from a 10 ft. board by placing in on a saw horse. The boy is 6 ft. from the saw horse. What weight must be placed on the other end of the board to just balance the boy?

Section II

Directions:- Fill in the blanks with - or - to indicate True or False. Supply the missing word where necessary.

- _____ 1. Heat travels in waves.
- _____ 2. Solids expand on being heated.

- _____ 3. Water freezes at 32°C .
- _____ 4. Cold air rises.
- _____ 5. Metals are poor conductors of heat.
- _____ 6. White clothing absorbs more heat than does dark clothing.
- _____ 7. The electric refrigerator depends upon the principle of "heat of fusion".
- _____ 8. Sound is energy.
- _____ 9. The pitch of a note depends upon the diameter of the wire producing it.
- _____ 10. Wood and metals carry sound.
- _____ 11. Curtains are hung at the back of theaters to reflect sound waves.
- _____ 12. Music and noise are the same thing, scientifically speaking.
- _____ 13. Sound travels faster than light.
- _____ 14. The length of a wire has no effect on the sound it produces.
- _____ 15. Sound is conducted through a vacuum.

- _____ 16. Echoes are caused by ---- of sound.
- _____ 17. An instrument used to measure the depth of the ocean is -----.
- _____ 18. Heat travels from the sun to the earth by a method called -----.
- _____ 19. Scientists use the ----- thermometer scale.
- _____ 20. 40°C . = ----^oF.

APPENDIX II

Unit Outlines

A. Machines

B. Heat

C. Sound

APPENDIX II

Unit I :-

Power to Do Things:-

(1) General Aims:

1. To impart a knowledge and understanding of the basic principles and workings of the machines which make our age an age of speed.
2. To create an interest and appreciation of the value of machines and inventors to our modern life.

(2) Specific Objectives:

1. To develop a picture of life as it must have been before "the machine age". The rise of "progressive" civilization.
2. To know what energy is - definition, forms, kinds and relationship, source, law of conservation of and convertibility.
3. To learn that work involves motion caused by force--that can be measured.
4. To understand that the unit of power is Horse Power and its measurement involves the time in doing work.
 - a. To know that $1 \text{ HP} = 33,000 \text{ ft. lbs. per minute.}$
5. To know the principle and workings of the six simple machines.
 - a. Lever - 1st, 2nd, and 3rd class.
 - b. Pulley

- c. Wheel and axle
 - d. Inclined plane
 - e. Screw
 - f. Wedge
6. To show that the pulley and the wheel and axle are really modified levers; and that the wedge and the screw are really modified inclined planes.
 7. To be able to recognize that complex machines are really several simple machines working together.
 8. To learn the principle, parts, operation, and care of,
 - a. Steam engine
 - b. Steam turbine
 - c. Gas Engine - carburetor
 - d. Diesel Engine.
 9. To realize that machines are only agents of work; that without the introduction of some form of energy, machines are useless. Also Transmission of power.
 10. To know the concept of mechanical advantage and from it be able to solve practical, every day, problems.
 11. To know that the efficiency of a machine is the output of energy over the input, and from this be able to solve practical, every day problems.

12. To understand the meaning and importance of friction and inertia -- both as an aid and as a hindrance to humanity.
13. To know the production of our chief source of power--Electricity and how it is used.
14. To understand to be able to scientifically define
 - a. energy b. work c. H.P. d. force
 - e. machine f. fulcrum g. Law of Levers
 - h. Mechanical advantage i. Efficiency
 - j. friction
15. To appreciate the application of machines in modern transportation.
 - a. Locomotive
 - b. Automobile
 - c. Roads
 - d. Bridges
 - e. Water transportation
 - f. Air
16. The effect of machines on our standard and speed of living.
 - a. What machines do for us.

(3) Suggested Pupil Activity

1. Written report on the life of man and his standards of living before the advent of complex machines.

2. List several activities involving the expenditure of energy. Trace each to source of energy. List several sources and types of energy.
3. Make a list of definitions--i.e. work, force, foot lb., energy, H. P., etc.
4. Work several problems involving work and H.P. (i.e. weight, lifting, motors, etc.)
5. Show that energy is not destroyed in doing work.
6. List examples and use of the six simple machines. Work problems involving each type. Show relationship of each type to others.
7. Resolve complex machines into simple machine constituents. Written reports on the work of famous inventors.
8. Written reports and diagrams of steam and gas engines.
9. List several machines--and sources of energy.
10. Solve problems involving M. A. and Eff. Written reports on efficiency of local machines.
11. List positive and negative aspects of friction and inertia.
12. Using some pupils bicycle as object of study, analyze for simple machines, Mechanical advantage.

(4) Suggested Demonstrations

1. Pendulum - to show difference and relationship between Potential and Kinetic Energy.
 - a. Demonstrate inertia.
2. Demonstrate three classes of levers.
3. Demonstrate various systems of pulleys.
4. Demonstrate wheel and axle (windlass).
5. Demonstrate use of inclined plane.
6. Demonstrate use of screw.
7. Demonstrate effects of friction and how it can be reduced.
8. Show how one form of energy can easily be converted to another form.
9. Demonstrate the steam engine.
10. Demonstrate the steam turbine.
11. Demonstrate the gas engine.
12. Demonstrate sets of gears.

(5) Bibliography

Clement, Collister, Thurston Our Surroundings
Syracuse, New York, Iroquois Pub. Co., (1934)
pp. 242-269.

Excellent for definitions.

Gruenberg Unzicker Science In Our Lives
New York, World Book Company, (1938) pp. 362-427.

Excellent Summaries, questions, and activities.
Good presentation.

Lake, Harley and Melton Exploring The World of Science
Boston, Silver, Burdett & Co., (1934) pp. 293-335.

Organized into several problem units. Good exercises.

Meister Living In A World of Science, Book II₁
Boston, Scribners & Low, (1935) Energy and Power,
pp. 1-12 120-233.

A long, but very adequate and interesting discussion of energy and power. Good reviews, tests and suggestions at end of each chapter.

Snyder General Science
Boston, Allyn Bacon, (1925), pp. 522-542.

Pretty meager. Only essential facts, dry, etc.

Watkins, Bedell General Science for Today
New York, MacMillan Co., (1936), pp. 259-284.

Excellent for unit questions and summary. Suggests outside "Things to do".

Weed, Rexford, Carroll Useful Science for High School
Chicago, J. C. Winston Co., (1935), pp. 137-185.

Brief, but fairly adequate write up. Contains experiments to be done and good questions.

Wood & Carpenter Our Environment
pp. 45-68.

Good reviews and questions. Better books available.

Department of Public Instruction Courses of Study
for High School General Science, Published by
State of Iowa, (1930), pp. 54-56.

Paul C. Stetson Course of Study in General Science
Indianapolis Public Schools. (1935) pp. 81-83.

Idaho Bulletin of Education, Tentative courses of
Study, Boise, Idaho, Idaho State Board of Edu-
cation, (July, 1933) Vol. XIX, No. 1.

Unit II:- Fire and Heat

(1) General Aims:-

To impart a knowledge and understanding of the origin, nature, importance and use of fire and heat in our every day life.

(2) Specific Objectives:-

1. To realize the place of fire in modern civilization--how early man began to make fire his slave and how we are almost completely its master today. (Read Science in Our Lives pp. 203-277).
2. To know the essentials for burning.
 - a. Oxygen
 - b. Combustible material
 - c. Kindling temperature.
3. To recognize heat as a form of energy and to appreciate it as the source of most of man's power. The Theory of Heat.
4. To recognize the sources of heat.
5. To know the properties of radiant energy.
(Transmission, reflection and absorption.)
6. To know the effect of heat on solids, liquids and gasses--expansion and contraction.
7. To understand the principles involved in thermometers and thermostats.
 - a. Mercury
 - b. Alcohol
 - c. Water
 - d. Air

8. To understand the Fahrenheit and Centigrade thermometer scales.
9. To know the significance of "absolute zero".
10. To distinguish between heat and temperature.
11. To understand what is meant by B. T. U. and calorie.
12. To know the principles of
 - a. Heat of vaporization
 - b. Heat of fusionand their uses.
13. To know how heat is "passed along".
 - a. Conduction
 - b. Convection
 - c. Radiation
14. To learn how passage of heat can be controlled.
 - a. Insulators, etc. (thermos bottles, fireless cookers, etc.)
15. To know the principle of the ice refrigerator.
16. To know the principle of the gas and electric refrigerator.
17. To know the underlying principles of the various methods of heating homes.
 - a. Fireplace
 - B. Hot air
 - c. Steam Heating
 - d. Electricity
 - e. Gas and oil burners.

18. To know the use of heat in ventilation.
19. To understand and define:-
- a. Heat b. Thermostat c. Thermometer d. C° ;
 - F° e. Absolute zero f. temperature g. B.T.U.
 - h. Calorie i. Heat of vaporization j. Heat
 - of fusion k. Volatile l. Conduction m. Con-
 - vection n. Radiation o. Insulation

(3) Suggested Pupil Activities

1. Written report on development of fire and fire making. Use of fires up thru the ages and methods of making it and putting out.
2. Discuss the essentials for burning.
3. List sources of heat and evaluate.
4. Study a burning candle. Report what happens to all parts. New products formed?
5. Report on types of matches and how they work.
6. Describe the various types of thermometers and explain how they work.
7. Work problems involving the conversion of Fahrenheit to Centigrade and vice versa.
8. Write a theme on "What Absolute Zero means to Me".
9. List examples of heat and of temperature. Formal definitions.
10. Solve problems involving measurement of heat (B.T.U., calorie)

11. Report on uses of heat of vaporization and heat of fusion principles in or near Amherst.
12. List methods of heat passage. Several examples of each.
13. Report types of fire extinguishers. Parts and how used.
14. Report on refrigeration plants in stores and homes.
15. Report on means of heating homes.
16. Report on ventilation systems in Amherst.

(4) Suggested demonstrations:-

1. Burn a candle or matches in a closed box to show essentials of burning.
2. Make illuminating gas.
3. Expt. 59 page 191. Useful Science for H. S.
4. Demonstrate metal ball and ring.
5. Demonstrate compound bars and thermostats.
6. Construct several thermometers.
7. Balloon and flash to show effect of heating of air.
8. Demonstrate various kindling temperatures.
Fuels, etc.
9. Demonstrate passage of heat along a metal bar--
use paraffin, etc.
10. Show what happens to liquids when they are heated.
11. Show convection by means of beaker of water and

sawdust.

12. Demonstrate vacuum bottle and fireless cooker.
13. Demonstrate types of matches.
14. Analyze Bunsen Burner.
15. Demonstrate heat of vaporization and fusion with ether beaker and block experiment.
16. Demonstrate H_2SO_4 $NaHCO_3$ fire extinguishers.
17. Show effects of CO_2 on fire.
18. Make water boil at less than $100^\circ C$.

(5) Bibliography

Clement, Collister, Thurston Our Surroundings
Syracuse, N.Y., Iroquois Pub. Co., (1934)
pp. 81-117.

Excellent Summaries and Definitions

Gruenberg, Unzicker Science In Our Lives (1938)
pp. 205-277. (Require pp. 203 and 277-279.)

Excellent summaries, questions, units, activities. Very good text.

Lake, Harley and Welton Exploring The World of Science, Boston, Silver Burdett & Co., (1934), pp. 336-385.

Problem units, good exercises for test drills.

Meister Living In A World of Science - Book I
Boston, Scribners & Sons, (1935), Heat and Health, pp. 1-174.

Again, a long discussion, but very adequate and interesting. Useful in reports. Good reviews and tests at end of chapters.

Watkins, Bedell General Science for Today Mac-Millan Co., (1936), pp. 285-329.

Good organization of basic problems. Excellent summaries and suggestions.

Weed, Rexford and Carroll Useful Science for High School, Chicago, J. C. Winston Co., (1935), pp. 186-224.

Brief summary of Heat. Experiments and questions.

Dept. of Public Instruction Courses of Study of High School General Science, Des Moines, Published by State of Iowa, (1930), pp. 36-41.

Paul C. Stetson (compiler) Course of Study in General Science, Indianapolis Public Schools, (1935), pp. 37-40.

Idaho State Board of Education Tentative Courses
of Study in General Science, Biology, Chemistry,
and Physics for High Schools. (July, 1933).
XIX, No. 1, pp. 39-41.

Unit III:- Sound

(1) General Aims:-

1. To impart a knowledge and understanding of the basic principles and applications of sound.
2. To create an interest and an appreciation of the influence of sound on man and his daily life.

(2) Specific Objectives:-

1. To know what sound is--how it is created.
2. To understand how sound travels
 - a. Through air.
 - b. Through other matter--hard, dense, and soft fibrous.
 - c. Relative speeds. Compare light.
3. To know that sound is reflected.
 - a. Applications of this principle.
4. To know why sounds differ.
 - a. Loudness
 - b. Pitch
 - c. Quality
5. To know the difference between music and noise.
 - a. Harmony
 - b. Chords
 - c. Overtones
6. To know the parts of the ear, its care.
 - a. How the ear receives sound.

7. To know how the voice is produced.
 - a. To learn how to care for and cultivate the voice.
8. To know and understand some of the means of reproducing and transmitting sound.
 - a. Phonographs and records.
 - b. Telephone.
9. To become acquainted with various types of musical instruments and to know their underlying principles.
 - a. Stringed instruments
 - b. Wind instruments
 - c. Percussion instruments
10. To realize how sound enhances our lives.

(3) Suggested Pupil Activities:-

1. List several objects which create sound and find a common principle exhibited.
2. Describe an experiment to show the relative speeds of sound in various types of matter.
3. Calculate how far away storms are--knowing time of flash and thunder.
4. Examine some area where echoes are produced.
5. Write a paper on instruments which use principles of sound.
6. Write a paper on auditoriums and sound difficulties.

7. Write a paper on the "Voice and Ear--Its Use and Care".
8. Examine a Phonograph and a record. Report.
9. List several instruments--classify and explain principle on which they work.
10. Solve problems involving depth and altitude measurement.

(4) Suggested Demonstrations

1. Demonstrate the production on sound by vibrations.
 - a. Tuning forks and pitch ball.
 - b. Comb and tissue paper.
 - c. Stringed instruments.
2. Show that sound travels thru wood, iron, water; etc.
3. Show that sound does not travel in vacuum.
4. Compare echoes to waves of water being reflected in a pan.
5. Determine velocity of sound in air.
6. Illustrate how loudness, pitch and quality of sound can be controlled.
 - a. Use sonometer
 - b. Violin
7. Diagram. ear and "voice box".
8. Demonstrate making of records and use of phonograph.
9. Make a tin-can telephone.

10. Demonstrate several whistles.

11. Demonstrate several musical instruments.

(5) Bibliography

Clement, Collister, Thurston Our Surroundings
Syracuse, N.Y., Iroquois Pub. Co., (1934),
pp. 170-179.

Short treatise of sound, but includes all necessary information. Best used as outline by students.

Gruenberg, Unzicker Science In Our Lives
World Book Co., (1938), pp. 642-670.

Good logical development of sound.

Lake, Harley, and Welton Exploring the World of Science
Boston, Silver Burdett & Co., (1934),
pp. 50-67.

Excellent presentation of sound in a very understandable way. Not too elementary nor too complex.

Watkins, Bedell General Science for Today
MacMillan Co., (1936), pp. 421-454.

Very good for the connection between electricity and sound.

Weed, Rexford, and Carroll Useful Science for High School
Chicago, J. C. Winston Co., (1935), pp. 225-254.

Good text for ninth grade science. Good experiments and not too much theory.

Department of Public Instruction Courses of Study of High School General Science
Des Moines, Published by State of Iowa,
pp. 68-71.

Idaho State Board of Education Tentative Courses
of Study in General Science, Biology, Chemistry,
and Physics for High Schools
(July, 1933), XIX, No. 1., pp. 37-39.

APPENDIX III

The Questionnaire

Please indicate with a (✓) in the "Yes" or "No" column whether or not the following statements express your opinion. Read each statement carefully and make sure that when you say "Yes" you agree with the statement and when you say "No" you disagree with the statement.

Yes No

- | | | |
|-------|-------|---|
| _____ | _____ | 1. I liked to study science under the Socialized classroom procedure. |
| _____ | _____ | 2. I liked both methods equally well. |
| _____ | _____ | 3. I spent more time studying under the socialized procedure. |
| _____ | _____ | 4. I spent less time studying under the socialized procedure. |
| _____ | _____ | 5. I spent about the same amount of time studying under both. |
| _____ | _____ | 6. "General Science Bees" helped me to learn science more easily. |
| _____ | _____ | 7. "General Science Bees" helped me to find fun in science. |
| _____ | _____ | 8. I spent much time finding questions for the Bees. |
| _____ | _____ | 9. The questions that I collected were helpful in learning Science. |
| _____ | _____ | 10. I studied less than usual on nights before we have "Science Bees". |
| _____ | _____ | 11. It was unpleasant to be called on by surprise. |
| _____ | _____ | 12. I liked to surprise my friends by calling on them. |
| _____ | _____ | 13. It was very helpful to be able to call on another pupil when I couldn't answer some question. |
| _____ | _____ | 14. I tried to think up some "sticker" questions for the smart ones in the class. |
| _____ | _____ | 15. I think that the pupils who "pass on" their questions to their friends are "buck passers". |
| _____ | _____ | 16. It was harder to remember the things we talked about in general class discussions than it was to remember the things the teacher told us. |
| _____ | _____ | 17. The discussions and Bees made it easy for me to remember science facts and principles. |
| _____ | _____ | 18. I disliked the frequent quizzes. |
| _____ | _____ | 19. I often had questions that the teacher asked on quizzes. |
| _____ | _____ | 20. I liked to outguess the teacher in making up questions. |
| _____ | _____ | 21. I didn't like to have to talk in class discussions. |
| _____ | _____ | 22. The class discussions were dull and boring. |
| _____ | _____ | 23. In class discussions I tried to tell about things in General Science that I did myself. |
| _____ | _____ | 24. Science was more interesting when the teacher lectured or asked questions than when we had discussions or "Bees". |
| _____ | _____ | 25. I learned many things that I didn't know from my friends during class discussions. |

Yes No

- _____ _____ 26. I would rather have the teacher explain all the Science principles without having to take part in class discussions.
- _____ _____ 27. I had more class freedom under the Socialized procedure.
- _____ _____ 28. I disliked being free to do Science as I wanted to do it.
- _____ _____ 29. I would rather have definite assignments in the text book everyday.
- _____ _____ 30. I seldom learned any science by writing reports on various units.
- _____ _____ 31. I did more outside reading for class discussions than I did before we had them.
- _____ _____ 32. I would rather study Science by the Socialized procedure than by the text book method.
- _____ _____ 33. I would like a General Science Bee more than once a week.
- _____ _____ 34. I found many personal interests by browsing around in science books.
- _____ _____ 35. I liked to study science under the socialized classroom procedure.
- _____ _____ 36. It was harder to remember the things we talked about in general class discussions than it was to remember the things the teacher told us.
- _____ _____ 37. In class discussions I tried to tell about things in General Science that I did myself.
- _____ _____ 38. Science was more interesting when the teacher lectured or asked questions than when we had discussions or "Bees".
- _____ _____ 39. The discussions and Bees made it easy for me to remember science facts and principles.
- _____ _____ 40. Which method do you want to study under for the rest of the semester? Why?

APPENDIX IV

- A. Calculations of the Reliability of the "Gruner Science Test".
- B. Sample calculations of Mean, Standard Deviation, etc.

A. Reliability Calculation:-

Correlating individual scores on odd questions
with their scores on even questions,

$$r = .876 \pm .023$$

using this r in the Spearman Brown Prophecy
formula,

$$r_x = \frac{N \times r}{1 + (N-1) \cdot r}$$

$$r_x = \frac{2 \times .876}{1 + (2-1) \cdot .876}$$

$$r_x = .935$$

The index of reliability = $\sqrt{r_x} = \sqrt{.935} = .96$

B. CALCULATION OF THE MEAN AND STANDARD DEVIATION OF GAINS OBTAINED ON THE "GRUNER SCIENCE TEST" BY GROUP A DURING THE FIRST SECTION OF THE EXPERIMENT

X	f	d	fd	fd ²
65 //	2	6	12	72
60 ///	3	5	15	75
55	0	4	0	
50 //	2	3	6	18
45 /	1	2	2	4
40 //	2	1	2/37	2/171
35 /////	5	0	0	0
30 ///	3	-1	-3	3
25 /	1	-2	-2	4
20 //	2	-3	-6	18
15 //	2	-4	-8	32
10	0	-5	0	
5	0	-6	0	
0 /	1	-7	-7/-26	49/106
	<u>N = 24</u>		<u>fd = 11</u>	<u>fd² = 277</u>

$$M = M_1 + \left(\frac{fd}{N}\right) i = 37.5 + \left(\frac{11}{24}\right) 5 = M = 39.8$$

$$\sigma = \left(\sqrt{\frac{277}{24} - \left(\frac{11}{24}\right)^2}\right) 5 = 16.85$$

CALCULATION OF THE MEAN AND STANDARD DEVIATION
OF GAINS OBTAINED ON THE "GRADUATE SCIENCE TEST"
BY GROUP B DURING THE FIRST SESSION OF THE
EXPERIMENT

X	f	d	fd	fd ²
80 /	1	8	8	64
75 //	2	7	14	98
70 //	2	6	12	72
65 /	1	5	5	25
60	0	4	0	
55 /	1	3	3	9
50 /	1	2	2	4
45 //	2	1	2/46	2/274
40 ////	4	0		
35 /	1	-1	-1	1
30 /	1	-2	-2	4
25 /	1	-3	-3	9
20 ////	4	-4	-16	64
15 /	1	-5	-5	25
10 /	1	-6	-6	36
5	0	-7	0	0
0	0	-8	0	0
-5	0	-9	0	0
-10 /	1	-10	-10/43	100/239
$\Sigma = 24$			$\Sigma fd = -3$	$\Sigma fd^2 = 513$

$$M = 42.5 + \left(\frac{-3}{24}\right) 5 = 43.13$$

$$\sigma = \left(\sqrt{\left(\frac{513}{24}\right) - \left(\frac{-3}{24}\right)^2}\right) 5 = 23.10$$

Calculation of the Standard Error of the Mean:

$$S.E._m = \frac{S.D}{\sqrt{N}}$$

Group A during first section of the experiment:

$$S.E._m = \frac{16.8}{4.9} = 3.44$$

Group B during first section of the experiment:

$$S.E._m = \frac{23.1}{4.9} = 4.71$$

Calculation of the standard error of the difference between two means:

$$S.E._d = \sqrt{S.E._m^2 + S.E._m2^2}$$

$$S.E._d = \sqrt{(3.44)^2 + (4.71)^2} = 5.8$$

Calculation of the Critical Ratio:

$$C.R. = \frac{\text{Difference between means}}{S.E._d}$$

$$\frac{3.3}{5.8} = .57$$

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