A CRITICAL STUDY OF THE RELATIVE VALUE OF THE LABORATORY METHOD VERSUS THE GENERAL CLASS METHOD OF TEACHING PHYSICS

by

Raymond C. Perrussel

B.S. Ottawa University, 1921

Submitted to the Department of Education and the Faculty of the Graduate School of the University of Kansas in partial fulfillment of the requirements for the degree of Master of Arts.

Approved by:

J.W. Twente
Instructor in charge

Raymond A. Schwegler
Head of the Department

July, 1930.

ACKNOWLEDGMENT

The writer wishes to express his sincere thanks and appreciation to Dr. J.W. Twente, School of Education, University of Kansas, for his many helpful suggestions and criticisms in the writing of this thesis; and to his wife for her encouragement and patient assistance in the preparation of the data for this study; and to the science teachers who so kindly assisted in the collection of the data for this thesis.

R.C.P.

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CHAPTER I

INTRODUCTION

From the leading school journals and educational writings, it seems there is a question as to the value derived from laboratory teaching.

Many of the discussions are based purely on psychological principles, but a fairly large number of studies have been carried out on different phases of this problem. As far as the writer has been able to discover from the literature in this field, no experiment has been attempted which would evaluate the effectiveness of the laboratory process over the regular class room work.

Never-the-less the true value derived from the time spent in the laboratory, as well as the monetary cost, is a vital educational problem to both the teacher and administrator.

If it could be shown that the laboratory period was not as productive as we could reasonably expect, steps should be taken which would lead to a revision of the laboratory procedure, as now followed, by either changing our methods for practices which would be more effective, or, by a reorganization of the course on a new time distribution scheme.

It will be the purpose of this study to determine the effectiveness of laboratory teaching of fundamental principles of high school physics and their applications, as compared with the lecture discussion method of teaching. The results will be secured through the use of tests made up of questions secured from a number of standardized tests in the field of physics.

CHAPTER II

RELATED LITERATURE

Developments of Physics

Physics was not introduced into the curriculum of secondary schools as a regular study until about the middle of the last century. We have available fairly definite evidence of the character of the work done at this early date, from the text books which have been handed down from that period. The subject matter differed but little from present day books but the method of treatment differed decidedly. It was a method essentially informing in character, in which the author gave mainly dogmatic statements, the laws of physics along with many interesting but unrelated facts of the science. There was little or no indication of the experimental processes by which this scientific material had been developed.

The laboratory features of the secondary school treatment were not introduced until late in the seventies; only a very few high schools pretended to give any laboratory instruction as late as 1880. The growth of the laboratory idea was evident for Gage's "Elements of Physics" appeared at this time and it was fairly well imbued with the idea of individual experimentation. (p. 151)[1*]

About 1886 Harvard began to lead the colleges of the country by adding to its entrance requirements, laboratory instruction entrance requirements, laboratory instruction. This brought about a radical change with emphasis placed on laboratory teaching. Little recognition was

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*Numbers in text refer to the corresponding numbers in the bibliography.

given to the facts that the fundamental outlook of science, acquired in this manner, was decidedly fragmentary, as the time available was not sufficient for a large enough number of individual experiments to cover the field in a thorough fashion. This change proved to be too great and Harvard, in 1897, modified its requirements suggesting that more emphasis be placed on text discussion and lecture demonstration. (pp. 450-51).[2]

The progress of the laboratory idea in the West proceeded with more deliberation, yet the state of affairs, generally, has the advantage and the strength which are the results of a steady growth. (p. 153)[1]

As examples of the specifications of the physics unit made by various organizations; those made by the North Central Association of Colleges and Secondary Schools, in 1908, and the requirements set by the College Entrance Examination Board of 1909 are representative. They differ only in minor unessential features. The requirements which refer to laboratory follow:

> 1. The unit of physics consists of at least one hundred and eighty periods of forty five minutes each of assigned work. Two periods of laboratory work counts as one of assigned work.
>
> 2. The work consists of three closely related parts; namely, class work, lecture demonstration work, and laboratory work. At least one fourth of

the time shall be devoted to laboratory work.(pp. 156-67)[1]

Controversies over Laboratory Methods.

The laboratory idea met opposition, much the same as every new theory, in any field, has experienced. Serious controversies have existed almost from the time of its inception.

Dewey quotes the following statement from Jevous: "Observations as conducted by scientific men are effective only when excited and guided by hopes of verifying a theory. The number of things which can be observed and experimented on are infinite and if we set to work to record facts with no purpose our records will have no value".

Dewey referring to this statement, says, "The first statement is not wholly sound, but the principle that scientific men never make observations an end in itself, but always a means to a general intellectual conclusion, is true. (p. 192)[3] He also states, "Learning in the proper sense is not learning things but the meaning of things". (p. 176)[3]

Thorndike in his discussion of the laboratory method says, "Like any reform in education, the laboratory method has suffered at the hands of its friends, by being used indiscriminately and by being over-used. It is not scientific to spend two hours in learning, by the manipulation of instruments, something which could be better learned in two minutes by thought. Washing bottles, connecting electric wires and putting away test tubes, though doubtless useful tasks in connection with scientific housewifery, are not magical sources of intellectual growth. Nor is it safe to disregard what is taught, so long as it is taught as an exercise in scientific method. A laboratory should teach facts important in themselves. It is disastrous to scientific habits in the young for them to find repeatedly that elaborate experimental work brings at the end some trivial or meaningless results". (pp. 178-79)[4]

H.E. Clifford of the Massachusetts Institute of Technology reporting before the Eastern Association of Physics Teachers, in 1917, said, "In any course of physics the fundamental instruction should be by class room work which should be made more vital by the laboratory. The class room comes first in usefulness and efficiency in instilling the fundamental ideas, and the laboratory second. A well illustrated course of lectures is more valuable than a well equipped laboratory". (p. 32)[5]

Parker states, "Unless careful steps are taken to avoid it, there is probably more time wasted in laboratory work than in any other type of high school exercise". He goes on to say that the very form or technique of laboratory work offers more forms of diversion than are tolerated in a recitation form of a course. (pp. 35-36)[2]

In a later chapter he points out that if one considers the part played by experimentation in scientific procedure he will realize that laboratory exercises do not hold this same relationship in a student's thinking. A scientific investigator usually sets up some hypothesis and then sets out to prove it by devising some form out to prove it by devising some form of experimentation which will bear out his theorids. This procedure is very different from that employed in laboratories where students merely carry out some form of manipulations by a recipe. (pp. 459-60)[2]

In conclusion, Parker says, "In his enthusiasm the teacher becomes blinded to the fact that the laboratory process wastes a great deal of time in routine manipulations and really gives the student little useful information. (p. 463)[2]

Twiss, in his book says, "It is his opinion that two double periods of laboratory work in science with only three single periods devoted to class work as is the custom in many schools is not a desirable ratio. This process results in the neglect of the proper emphasis on important principles and applications. He states that in his opinion until teaching becomes much better than it now is a much more profitable ratio of time would be four single periods with only one double period devoted to laboratory work each week". (p. 133)[6]

Mann of Chicago says, that for general students, college laboratory work is neither essential nor desirable. This statement was made during that period when laboratory work received about half the time spent in the course. (p. 208)[7]

W.A. Noyes in discussing the relationship of laboratory work to the other phases of chemistry points out that laboratory procedure is incidental while text book work should hold the principal position. (pp. 748-50)[8]

E.R. Downing says, "If information is the chief end in laboratory instruction the laboratory manual may be sufficient to state the facts and principles, and the laboratory assistant, with its aid, may direct the process of its verification. But it is to be noted that the laboratory method of acquiring information is very wasteful of time. It should be used only when the concept involved is new and needs more clarifying by contact with materials. Most information, if students need it, is most economically acquired from books". The above ideas are made purely on psychological principles, to study pupils having had no training in laboratory procedure would be impossible. (p. 646).[9]

The question of the importance of laboratory work is asserting itself now, more than ever before, because of the following conditions:

1. Industrial education is receiving severe criticism from tradesmen who are condemning the plumber, carpenter or other artisan who is a laboratory product.

2. Technical institutions which in the past have been largely engaged in teaching the philosophy and mathematics of fundamental principles are now devoting themselves to laboratory proof of these theories.

3. A third reason for this discussion is the wide spread of laboratory procedure in the larger high schools. Administrators feel they must prepare their students for the fields they expect to and do, enter, namely: technical and professional.

4. The smaller and rural high school administrators feel they must copy the city schools.

These points are merely reasons for the present prominence of this question. The problem now arises, is laboratory work important enough in our educational scheme to warrant such prominence or should it be given greater emphasis? (pp. 606-08)[10]

Charles Watson reports that the prevailing tendency in the larger schools is to devote a larger ratio of time to the class period and less to the laboratory. (p. 91)[11]

He also found the experiments worked in our laboratories today are, to a large extent, the same as those worked thirty years ago. For example, he found 94% of the schools using the experiment on, "The Weight of a Lever and Its Center of Gravity", while only 56% took the experiment, "Testing the Acid in a Storage Battery" (pp. 99)[11]

Previous Studies Made

W.G. Bowers made a study of chemistry students in the Colorado State Teachers College, Greeley Colorado, for ten consecutive semesters by the following plan.

Students were enrolled in chemistry with the option of two recitations each week and one laboratory period for three hours' credit, or two recitations per week and two laboratory periods for four hours' credit. Two general examinations on the work covered in class and laboratory work were given each semester. Questions were selected without regard for those with only one period of laboratory as the class work covered all the material of the laboratory course. The results showed the students in two periods of laboratory had an average of 4.5 above those enrolled for only one period of laboratory. In his conclusions, Bowers says, "Since those working for four hours credit spent twice as much time in the laboratory and one third more time on the course as a whole, it might seem as though the last twenty five percent of the time was unprofitably spent. (pp. 611-13)[11]

John L. Spitler reports a study in physics and chemistry carried out in the four high schools of Kansas City, Missouri. Three of the schools were using two single periods of laboratory per week and one school used two double periods for laboratory each week.

The students of the physics and chemistry classes were given an initial and final test on their respective field. The tests were both standardized tests. The mean gains of the final over the initial test were determined. The reliability of any difference found was determined by the use of the S.D. of the difference of the means.

In order that only groups equal in mental capacity be compared, the "Otis-Self-Administering Test of Mental Ability" was given to each student considered in this study. Only the results of those students were used which could be matched with students of equal ability in each of the other schools on a basis of results obtained on the Otis' mental test. All papers of students not matched, or students failing to take all of the tests, and some doubtful papers, were discarded for the study. (pp. 18-40)[12]

While some results were found which favored the double period laboratory classes, in general the data at hand lead to the following general conclusion: "When we measure the results by standardized tests, the effectiveness of the teaching of physics and chemistry is not determined by the length of the laboratory period. (pp. 41-42)[12]

a. J.C. Chapman reports a study made by him in the Cleveland Schools to determine the extent to which present teaching accomplishes its purpose in securing a thorough grasp of the underlying principles. His work was applied to the division of mechanics. He arranged fourteen problems covering the ground of the usual high school course. These problems were arranged in order of simple to complex and each problem required only simple arithmetical calculations. These problems were given to 238 pupils of four of the Cleveland High Schools. This group consisted of 165 boys and 73 girls whose average age was 16.5 years. The test was given after they had completed the material. The time limit was forty minutes. He found by taking the whole group and averaging the results, each problem was correctly solved by only 15% of the pupils. He also found that no one problem was solved correctly by more than 69% of the pupils, and two problems were not solved correctly by anyone. (pp. 39-43)[13]

b. E.W. Kebler of the Hillsdale High School and C. Woody of the University of Michigan reported a study they made to evaluate the merits of individual vs. demonstration methods of teaching physics laboratory work. They equated two groups of students by the use of the Army Alpha Group test. Each group was made up of about the same ratio of good medium and poor students. The particular division of physics covered was the division on heat. Fourteen experiments were selected. These were divided into two groups. Seven were given to one of the equated groups for them to work. Written directions were supplied the pupils and they were permitted to perform the experiment individually in the laboratory. The other seven experiments were supplied to the other group in a different manner. The instructor performed the experiment in the presence of the students and gave them an oral explanation of the process. The pupils were then tested for definite information on the fundamentals of the experiment after all seven had been given. The demonstration group was found to be superior in two tests. The groups were then rotated and the other seven experiments were applied. The results in the second case were slightly different. It was found that the group who performed the experiments individually the second time were superior in three tests and the demonstration group was superior in three tests and the other test both groups were equal. It seemed that the group who were first taught by the demonstration method had acquired a better technique for the carrying on the experiment. It was proven that doing a thing with one's hands does not insure the knowledge of physics principles. (pp. 50-59)[14]

c. T.D. Phillips, Johnstown, Pennsylvania, describes a study carried on in that high school to determine the value of the note book and the effectiveness of different laboratory procedure. The study was made by testing a group of pupils on three different types of experiments. The first type was one which the pupil performed by himself and recorded in a note book. The second type was one performed by the instructor, the calculations and conclusions were drawn by the pupil and recorded in a note book. The third was the common demonstration type performed by the teacher, then discussed in class but no record was made in a notebook. The students were tested on each type for a description of the apparatus and the material, method of procedure, and the nature of the data and conclusions drawn. These divisions were graded as complete and accurate or acceptable or not satisfactory. Results.

Kinds of answers Satisfactory	app.	Method	Conclusions
Individual record	63%	48%	22%
Demonstration record	66%	44%	30%
Demonstration no record	45%	26%	26_

Kinds of Answers Passing	App.	Method	Conc.
Individual record	11%	26%	26%
Demonstration record	15%	26%	22%
Demonstration no record	22%	44%	26%

Kinds of Answers Failing	App.	Method	Conc.
Individual record	26%	26%	52%
Demonstration record	22%	30%	48%
Demonstration no record	33%	30%	48%

The first column shows the note book is more important than manipulation in the impressing of details of the apparatus and materials. The second column shows the same thing for the method and procedure. The first two columns do not show a great deal of difference for the individual vs. demonstration methods. The third column shows where reasoning and application of principles is a factor the demonstration and note book method are superior. The study seems to show laboratory procedure is not very fruitful from the stand point of mastery of fundamentals and their application. (pp. 451-53)[15]

d. J.L. Cooprider--Central High School, Evansville, Indiana, reports the results of an experiment in high school biology laboratory work. He compared oral vs. written instruction anddemonstration vs. individual methods of work. Rather difficult exercises of different nature were selected. These exercises were given to forty-two pupils of the sophomore year who were divided into three groups having been equated by the Chicago group intelligence test. Each group consisted of fourteen pupils. Four different methods were used.

Written directions with demonstration exercises

Written directions with individual exercises

Oral directions with demonstration exercises

Oral directions with individual exercises.

The exercises were divided into four parts for the purpose of grading, namely object of experiment procedure, results, and conclusion. Each part that was correct was scored one point and these points were later changed into percents. The percents were later added for the four exercises and divided by four giving a total score for the exercise in terms of percents. This gave each division of the exercise equal weight in the total score. It was found that oral instructions were better than written instructions. It was also found that superior results were obtained by the demonstration exercises in those divisions where reasoning was necessary. Relatively poor results were obtained in terms of percents of principles found correct in the division termed conclusion. Results follow;

Oral directions demonstration exercise 48.1%

Written directions demonstration exercise 32.2%

Oral directions individual exercise 55.3%

Written directions individual exercise 27.0%

This seems to indicate relatively poor results are obtained in knowledge and application of principles as taught by the present laboratory methods. The memory phases of these same exercises had an average score of 90-86%. In all of these experiments all results seem to point to the fact that the pupils attention is focused on the manipulation of the techniques of the exercise rather than on the development of principles. (pp. 838-884)[16]

Elliott R. Downing, of the School of Education University of Chicago, gives a summary of the studies published at that time, dealing with the relative values of laboratory teaching. In his discussion, he points out, in light of the data then available, that all the experiments show the lecture demonstration, as far as imparting information, is quite, or nearly, as efficient as the laboratory process and much more economical. In his opinion from the results of experimentation, students waste an enormous amount of time in the laboratory. (pp. 769-70).[17]

F.A. Riedel in a summary of all studies published up to the winter of 1926 which dealt with the relative effectiveness of demonstration and laboratory methods in science, says, "None of the studies was published in complete enough form to be able to criticize it, and not one could be repeated with a high degree of likeness."

It was pointed that all but two of the studies under his consideration were made on twenty pupils, or less, with a very small number of questions. Only one study took the precaution to validate the reliability of any of their findings by the use of accepted statistical procedure devised for that purpose.

Riedel leaves the impression that really little evidence has been advanced to give any substantial proof concerning the effectiveness of either method. (pp. 512-19)[18]

CHAPTER III

A. The General Problem

This thesis has to do with the relative effectiveness of the laboratory method and the general lecture and discussion method of teaching for the knowledge of the essential principles of high school physics, and the ability to apply those principles.

Through this experiment an answer will be sought for the following problems.

B. The Specific Problems

1. To determine the relative effectiveness of teaching for knowledge of principles of mechanics developed in the laboratory, with those principles developed only in general class work in mixed groups.

2. To determine the relative effectiveness of teaching for ability to apply principles of mechanics developed in the laboratory, with those principles developed only in general class work in mixed groups.

3. To determine the relative effectiveness of teaching for knowledge of principles of mechanics developed in the laboratory, with those principles developed only in general class work, for groups composed of boys.

4. To determine the relative effectiveness of teaching for ability to apply principles of mechanics developed in the laboratory, with those principles developed only in general class work, for groups composed of boys.

5. To determine the relative effectiveness of teaching for knowledge of principles of mechanics developed in the laboratory, with those principles developed only in general class work, for groups composed of girls.

6. To determine the relative effectiveness of teaching for ability to apply principles of mechanics developed in the laboratory, with those principles developed only in general class work, for groups composed of girls.

7. To determine the relative effectiveness of teaching for knowledge of principles developed in mechanics by the general class method, between boys and girls.

8. To determine the relative effectiveness of teaching for ability to apply principles developed by general class methods, between boys and girls.

9. To determine the relative effectiveness of teaching for knowledge of principles developed in mechanics by the laboratory method between boys and girls.

10. To determine the relative effectiveness of teaching for ability to apply principles developed by the laboratory method, between boys and girls.

The use of the phrases, knowledge of principles in mechanics developed by the laboratory method, or, the ability to apply principles developed by the laboratory method, when mentioned in this thesis will refer to a principle which was developed first in regular class work and again in the laboratory. The term developed in regular class work will refer to principles that have been developed only in the regular class work and not in any laboratory procedure mentioned in the adopted "course of study for Kansas".

The answers to the above problems will be made from the study of the results obtained from eighteen high schools situated in various parts of the state of Kansas.

CHAPTER IV

METHODS OF PROCEDURE

The method used was a modified form of the investigation type. The study was made by survey.

During the first week in October, 1926, a letter, with a short questionnaire attached, was sent to thirty-two Kansas high schools. A form of this letter and questionnaire may be found in the appendix to this thesis.

The letter explained the nature of the proposed study and asked the various schools for their cooperation and willingness to give the four tests to their respective classes, at the time they had completed the work to page 193 in the state adopted text, "Black and Davis' Practical Physics", with all the related laboratory work.

The questionnaire was for the convenience of the schools solicited in making their reply.

It contained questions covering the following items: willingness to give tests, number of pupils enrolled in physics, and the time they expected to complete the material under consideration for this study.

Twenty-five replies were received to this first request. This was a seventy-eight per cent reply of the thirty-two requests. Twenty-four schools stated their willingness to cooperate in this study. The one negative reply was due to the fact that physics was not offered that year.

The time indicated for giving the tests varied from the last week in December to the second week in January. Tests were mailed to the twenty-four schools indicating their willingness to cooperate in this study. A direction sheet, giving specific directions to the teacher for administering the tests, along with directions to be read to the pupils before beginning the tests, was inclosed with the tests. The direction sheets were used as a precaution in an attempt to make the method of administering the tests uniform, in order that all scores secured should be comparable.

Eighteen towns responded with their class results, returning tests for each pupil in the class. This was a seventy-five per cent return from the number stating their willingness to assist with the study, or fifty-six per cent of the original number of schools asked to participate. The eighteen schools contributed 427 cases upon which this study is based.

All scores of the individuals who had not taken all four of the tests were discarded, along with several questionable papers. The failure of six schools in returning papers for their classes was probably due to the results made on the two tests for application of principles, which proved to be considerably poorer than the results obtained on the two tests for knowledge of principles.

As it would be impossible to make a study of this nature with a sufficient number of pupils who had not been subjected to any laboratory training, a plan was devised through tests devised in the following manner:

Four tests were constructed; one test of eighteen questions for determining the knowledge of principles which were developed only in the regular class work; the second test consisted of eighteen questions which were devised to test the ability of the pupil to make applications of those principles which were developed only in regular class work. The third test consisted of nineteen questions for measuring the knowledge of principles which were developed in the regular class work, and also covered in the laboratory experiments.

The fourth test consisted of nineteen questions for measuring the ability of the pupils to make application of these principles which were developed both in regular class work and in the laboratory.

These tests were constructed by using questions from the following standard physics tests: Starch's, "Mutilated Sentence Test", Camp's, "Iowa Physics Test", and Thorndike's, Reuh's, and Chapman's tests. The reason for using only portions of these tests is that each of these tests contains principles not covered by the adopted text of Kansas. This would not give a fair measure of the knowledge of principles.

Some of the tests were scored by the teachers who gave the tests. These were all rechecked, by office help, according to keys prepared by the author of this study.

The remaining tests were scored in the same manner and later rechecked. Due to the fact that the four tests did not contain the same number of test items the raw scores were changed into percentages in order to make the measure of central tendency comparable. The tabulations were all made in terms of this revised score, by the author, with the assistance of his wife. The frequency distribution of all the scores for the different phases of this study were made in step intervals of five.

CHAPTER V

THE PRESENTATION AND INTERPRETATION OF THE DATA

A. Measures of Central Tendency and Variability

The results of this study will be determined from a careful analysis of the tables of the frequency distribution of correct answers made on each of the four tests, mentioned in Chapter III.

The results will be interpreted in the light of the following statistical measures. The central tendency will be determined by means of the median. The variability of the results secured will be determined by the Standard Deviation (S.D.) from the median. The S.D. was selected for this purpose because it would give the range in variability of 68% of the cases. The reliability of the medians obtained in the several distributions will be determined by means of the Standard Deviation Median (S.D. median). This measure will give us the range between which the obtained median in this experiment may be expected to fall from the true median of each of the tests, if it had been given to all the possible cases.

In order to interpret with some degree of surety any apparent differences obtained in any of the measures of the central tendency, the Standard Deviation of the differences between any two measures in question, will be determined. The degree of surety with which we can draw conclusions from the differences of the medians and the S.D. difference of these differences will be determined. Through the use of the "Experimental Coefficient" explained by McCall in his book, "How to Measure in Education", this will be converted into a relation by chances of probability the same result would be secured if the experiment were repeated, (p. 405)[19]

The results have been collected into fourteen tables. Tables I - XII contain a frequency distribution of the correct answers, number of cases, median, Standard Deviation from the median, and the Standard Deviation Median for each of the following groups for study:

Table I gives a frequency distribution of the correct scores, based on one hundred, for the test on knowledge of principles taught in regular class work only. This table represents the scores made by the mixed group. The median score, or point above which fifty percent of the scores fell, was 54.55. This means that half of the cases included in this study answered correctly 54.55% of the questions dealing with the knowledge of principles.

The Standard Deviation for this group on the first test was 20.997. This means that 68% of the cases included in this study made scores between 75.54 and 23.56.

The standard deviation median for the mixed group on the first test was 1.2697. McCall, in his book "How to Measure in Education" (pp. 401) says ± 3 S.D. median is practical certainty. This, applied to data in this study, would give the following results: If the true median for all possible cases could be found we could feel certain it would never be greater or less than 54.55 ± 3 x 1.2697, or it might fall between 58.35 and 50.75.

Table II gives a frequency distribution of the correct scores, based on one hundred, for the test on ability to apply principles taught in regular class work only. This table represents the scores made by the mixed group. The median score was 36.66. This means that half of the cases included in this study answered correctly only 36.66% of the questions or less.

The S.D. for the mixed group on the second test was 18.793. This means that 68% of the cases included in this test made scores between 55.45 and 17.87.

The standard deviation median for the mixed group on the second test was 1.1366. It can be said, with practical certainty, that the median 36.66 does not deviate from the true median by more than ± 3 x 1.1366. The true median then will fall between the limits 41.06 to 36.66.

Table III gives a frequency distribution of the correct scores, based on one hundred, for the test on knowledge of principles taught in regular class and laboratory work. This table represents scores made by the mixed group. The median score for this group on the third test was 54.95. Half of the cases included in this study answered correctly 54.95% of the questions or more.

The S.D. for the mixed group on the third test was 21.104. This means that 68% of the cases included in this study made scores between 54.95 ± 21.10 or between 76.05 and 33.85.

The standard deviation median for the group represented by Table III wqs 1.2763. It then becomes practically certain the median obtained in this experiment will not vary from the true median by more than ± 3 x 1.2763 or, if the true median could be determined or the experiment is repeated, the median would fall some where between 54.95 ± 3 x 1.2763 which is between 58.78 and 51.12.

Table IV gives a distribution of the correct scores for ability of the mixed group to apply principles taught in the laboratory and regular class periods. The median score for this group was 42.65. This means that half of the cases made a correct answer for 42.65% or more of the questions.

The S.D. for this group was 26.52. This means that 68% of the cases included in this study made scores between 69.17 and 16.13.

The standard deviation median for the mixed group on the fourth test was 1.604. From this it becomes practically certain that the true median will be a number between 42.65 ± 3 x 1.604 or between 50.77 and 34.53. Table V gives the frequency distribution of the correct scores made by the boys, on the basis of one hundred, for the test on the knowledge of principles taught only in regular class work. The median score made by the boys on this test was 54.53. This means that 50% of the boys answered correctly 54.53% or more of the questions.

The S.D. for the boys on the first test was 21.57, which is to say 68% of the boys made scores ranging between 54.53 ± 21.57 or between 76.10 and 32.96.

The S.D. Median for the boys in knowledge of principles taught only in class work was 1.705. The true median is certain to be a number between 54.53 ± 1.703. The true median for this test when given to boys would fall between 56.23 and 52.83.

Table VI gives a frequency distribution of the correct scores made by the girls, on the basis of one hundred, for the test on the knowledge of principles taught only in regular class work. The median score made by the girls on this test was 56.4. Half of the girls made a correct response for at least 56.4% of the questions or more.

The S.D. for the girls was 20.034, which is to say, 68% of the girls made scores ranging between 76.74 and 36.06.

The S.D. median for the girls in knowledge of principles taught only in regular class work is 1.88. The true median would therefore be a number between 56.4 ± 3x1.88 or between 62.04 and 50.76.

Table VII gives the frequency distribution of the correct scores made by the boys, on the basis of one hundred, for the test on the ability to apply principles taught only in regular class work. The median for the boys in this test was 36.25. Half or 50% of the boys made 36.25% or better of their answers correct and half of the boys made less than 36% of their responses correct.

The S.D. for the boys on this test was 18.95 which means that 68% of all the boys made scores which would fall some where between 36.25 ± 18.95 or between 55.20 and 17.30.

The S.D. median was 1.498 this means that with positive certainty the true median for this test when given to boys would fall between the scores 36.25 ± 3 x 1.498 or between 40.74 and 31.76.

Table VIII gives the frequency distribution of the correct scores made by the girls, on the basis of one hundred for the test on the ability to apply principles taught only in regular class work. The median for the girls in this test was 34.22. Half or 50% of girls made correct answers in 34.22% of the cases or more and 50% of the girls had less than 34% of their answers correct.

The S.D. for the girls on this test was 18.858 that means that 68% of all the girls made scores which would fall somewhere between 34.22 ± 18.858 or between 53.07 and 15.37.

The S.D. median for the girls was 1.77. This means that with positiv e certainty the true median for this test when applied to girls would fall between the scores 34.22 ± 3 x 1.77 or between 39.53 and 29.91.

Table IX gives the frequency distribution of the correct scores made by the boys, on the basis of one hundred, for the test on the knowledge of principles taught both in class and laboratory. The median for the boys on this test was 55.00. Half or 50% of the boys made 55% or more correct answers in this test.

The S.D. for the boys on this test was 21.48, which means that 68% of all the boys made scores which would fall somewhere between 55 ± 21.14 or between 76.14 and 33.86.

The S.D. median for the boys on this test was 1.6713. The true median for this test when given to boys would be between 55 ± 3 x 1.6713 or between 60.01 and 49.99.

Table X gives the frequency distribution of the correct scores made by the girls, on the basis of one hundred, for the test on the knowledge of principles, taught both in class and laboratory. The median for the girls in this test was 54.87. Half or 50% of the girls made 54.87% or more correct answers in this test.

The S.D. for the girls on this test was 21.054 which means that 68% of all the girls made scores which would fall somewhere between 54.87 ± 21.05 or between 75.92 and 33.82.

The S.D. median for the girls on this test was 1.9777. The true median for this test when given to girls would be between 54.87 ± 3 x 1.9777 or between 61.8 and 48.94.

Table XI gives the frequency distribution of the correct scores, made by the boys, on the basis of one hundred, for the test on the ability to apply principles taught both in the class and laboratory. The median for the boys in this test was 44.09. Half or 50% of all the boys made 44.09% or more correct answers in this test.

The S.D. for the boys on this test was 26.675 which means that 68% of all the boys made scores which would fall somewhere between 44.09 ± 26.675 or between 71.76 and 17.42.

The S.D. median for the boys on this test was 2.1087. The true median for this test when given to boys would fall somewhere between 44.09 ± 3 x 2.1087 or between 50.41 and 37.77.

Table XII gives the frequency distribution of the correct scores, made by the girls, on the basis of one hundred for the test on the ability to apply principles taught both in the class and laboratory. The median for the girls in this test was 40.22. Half or 50% of the girls in this study made 40.22% or more correct answers in this test.

The S.D. for the girls on this test was 26.321 which means that 68% of all the girls made scores which would fall somewhere between 40.22 ± 26.321 or between 66.54 and 13.9.

The S.D. median for the girls on this test was 2.4729. The true median for this test when given to girls would fall somewhere between 40.22 ± 3 x 2.4729 or between 47.63 and 32.81.

B. Measures of Reliability of the differences Found Between Various Groups.

From an inspection of the data in Table XIV the answers to the specific problems set up in Chapter III will be attempted. The results of this study will be determined by using the following statistical measures of reliability of the difference, the difference of medians, standard deviation differences, and the experimental coefficient as explained by McCall. (pp. 403-405.)[19]

Problems:

1. To determine the relative effectiveness of teaching mixed groups, for knowledge of principles of mechanics developed in the laboratory, with those principles developed only in the general class work.

From tables I and III we find a difference in the medians of .401 in favor of principles taught both in class and laboratory. Table XIV shows an S.D. difference for this difference of 1.809. McCall says we can be practically certain that the true difference between these two measures will be between .401 ± 3 (1.809) or from -5.026 to 5.828. Evidently there is some chance that the true difference is zero or even below zero. For the true difference to go below zero would make the experiment favor the principles taught only in class work. To determine just how much greater the chances are one way than the other will be determined through the use of the experimental coefficient which happened to be .0797 in this case. According to McCall this is practically the same as saying there are less than 16 chances to 10 that a difference would be found between the same two groups again.

2. To determine the relative effectiveness of teaching mixed groups for ability to apply principles of mechanics developed in the laboratory with those principles developed only in general class work.

From tables II and IV we find a difference in the medians of 5.99 in favor of the application of the principles taught in the class and laboratory. Table XIV shows an S.D. difference for this difference of 1.952. McCall says we can be practically certain that the true difference between these two measures will be between 5.99 ± 3 (1.952) or between +11.846 and +.134. Evidently there is some chance that there really are more chances that the true difference between these two will be in favor of the principles taught in the laboratory and class. To determine just how much greater the chances are one way than the other will be determined through the use of the experimental coefficient which happens to be 1.1039 in this case. According to McCall an experimental coefficient of 1 is practical certainty. In terms of chances there are 930 chances to 1 that a true difference will always favor the application of principles taught both in the laboratory and the regular class.

3. To determine the relative effectiveness of teaching boys for knowledge of principles of mechanics developed in the laboratory with those principles developed only in general class work.

From tables V and IX we find a difference in the medians of .47 in favor of principles taught both in class and laboratory. Table XIV shows an S.D. difference for this difference of 2.39. McCall says we can be practically certain that the true difference between these two measures will be between .47 ± 3 (2.39) or from +7.64 to -6.7. Evidently there is some chance that the true difference is zero or even below zero. For the true difference to go below zero would make the experiment favor the principles taught only in class work. To determine just how much greater the chances are one way than the other will be determined through the use of the experimental coefficient which happened to be .0707 in this case. According to McCall this is practically the same as saying there are less than 16 chances to 10 that there would be found any difference between the same two groups again.

4. To determine the relative effectiveness of teaching boys for ability to apply principles of mechanics developed in the laboratory with those principles developed only in general class work.

From tables VII and XI we find a difference in the medians of 7.84 in favor of the application of the principles taught in the class and laboratory. Table XIV shows an S.D. difference for this difference of 2.58. McCall says we can be practically certain that the true difference between these two measures will be between 7.84 ± 3 (2.58) or between +15.58 to + .10. Evidently there is a probability that there are really more chances that the true difference between these two will be in favor of the principles taught in the laboratory and class. To determine just how much greater the chances are one way than the other will be determined through the use of the experimental coefficient which happens to be 1.093 in this case. According to McCall there is practical certainty, or in terms of chances there are 930 chances to 1, that a true difference will be above zero and will always favor the application of principles taught both in the laboratory and the regular class.

5. To determine the relative effectiveness of teaching girls for knowledge of principles of mechanics developed in the laboratory with those principles developed only in general class work.

From tables VI and X we find a difference in the medians of 1.53 in favor of principles taught only in general class work. Table XIV shows an S.D. difference for this difference of 2.72. McCall says we can be practically certain that the true difference between these two measures will be between 1.53 ± 3 (2.72) or from +9.69 to -6.63. Evidently there is some chance that the true difference between these two measures will be between 1.53 ± 3 (2.72) or from +9.69 to - 6.63. Evidently there is some chance that the true difference is zero or even below zero. For the true difference to go below zero would make the experiment favor the principles taught in the laboratory. To determine just how much greater the chances are one way than the other will be determined through the use of the experimental coefficient which happens to be .2023.

According to McCall there is practically no certainty or in terms of chances there are 25 chances to 10 that a true difference will be above zero and that it would always favor the application of principles taught only in regular class work.

6. To determine the relative effectiveness of teaching girls for ability to apply principles of mechanics developed in the laboratory with those principles developed only in general class work.

From Table VIII and XII we find a difference in the medians of 6.0 in favor of the principles taught in the laboratory. Table XIV shows an S.D. difference for this difference of 3.03. McCall says we can be practically certain that the true difference between these two measures will be between 6 ± 3 (3.03) or between +15.03 and -3.03. Evidently there is a little chance that the true difference is zero or even below zero. For the true difference to go below zero would make the experiment favor the application of principles taught only in regular class work. To determine just how much greater the chances are that the true ability of girls to apply principles will favor those taught in the laboratory rather than those taught only in regular class work will be determined through the use of the experimental coefficient which happens to be -713. According to McCall there is considerable certainty that the true difference will favor the principles taught in the laboratory. In terms of chances it might be said the chances are slight, or 380 chances to 10, that the above difference would be found.

7. To determine the relative effectiveness of teaching for knowledge of principles developed in mechanics by the general class method between boys and girls.

From tables V and VI we find a difference in the median of 1.97 in favor of the girls. Table XIV shows an S.D. difference for this difference of 2.525. There is practical certainty that the true difference between these two measures will be between 1.97 ± 3 (2.525) or between +9.545 and -5.605. Evidently there are some chances that the true difference is zero or even below zero which would make the experiment favor the boys. To determine how much greater the chances are, that the true difference will favor the boys rather than the girls in ability to apply principles taught only in regular class work, will be determined through the use of the experimental coefficient which is .3174 in this case. There is practically no certainty that the true difference would favor the boys. In terms of chances there would be slightly over 39 chances to 10 that the true difference would favor the boys.

9. To determine the relative effectiveness of teaching for knowledge of principles developed in mechanics by the laboratory method between boys and girls.

From tables IX and X we find a difference in the median of .13 in favor of the boys. Table XIV shows an S.D. difference for this difference of 2.59. There is practical certainty that the true difference between these two measures will be between .13 ± 3 (2.59) or between +7.9 and -7.64. Evidently there is a considerable chance that the true difference is zero or even below zero and in favor of the girls instead of the boys. To determine how much greater the chances are, that the true difference will favor the boys rather than the girls in knowledge of principles taught in laboratory, will be determined through the use of the experimental coefficient which is .018 in this case. There is practically no certainty that the true difference would favor the boys. In terms of chances there would be practically 10 chances to 10 that the true difference would favor the boys.

10. To determine the relative effectivenss of teaching for ability to apply principles developed by the laboratory method between boys and girls.

From tables XI and XII we find a difference in the medians of 3.87 in favor of the boys. Table XIV shows an S.D. difference for this difference of 3.24. There is practical certainty that the true difference between these two measures will be between $3.87 \pm 3 (3.24)$ or between + 13.59 and -5.85.

Evidently there is considerable chance that the true difference is zero or even below zero and in favor of the girls instead of the boys. To determine how much greater the chances are, that the true difference will favor the boys rather than the girls in ability to apply principles taught in the laboratory, will be determined through the use of the experimental coefficient which is .43 in this case. This is practically half certainty that the true difference would favor the boys. In terms of chances there would be slightly over 65 chances to 10 that the true difference would favor the boys.

TABLE I

Distribution of Scores for Knowledge of Principles not Taught in the Laboratory for the Mixed Group

0 - 5	7
5 - 10	7
10 - 15	3
15 - 20	10
20--25	6
25 - 30	20
30 - 35	16
35 - 40	35
40 - 45	18
45 - 50	36
50 - 55	61
55 - 60	18
60 - 65	49
65 - 70	26
70 - 75	34
75 - 80	17
80 - 85	35
85 - 90	15
90 - 95	14
95 - 100	0

N 427

$\frac{N}{2} = 213.5$

Median = 54.55

S.D. = 20.997

S.D. Median = 1.2697

TABLE II

Distribution of Scores for Ability to Apply Principles not Taught in the Laboratory, for the Mixed Group

0 - 5	11
5 - 10	6
10 - 15	16
15 - 20	45
20 - 25	32
25 - 30	46
30 - 35	56
35 - 40	45
40 - 45	30
45 - 50	0
50 - 55	40
55 - 60	29
60 - 65	33
65 - 70	17
70 - 75	11
75 - 80	4
80 - 85	5
85 - 90	1
90 - 95	0
95 - 100	0

N 427

$\frac{N}{2}$ = 213.5

Median = 36.66

S.D. = 18.793

S.D. Median = 1.1366

TABLE III

Distribution of Scores for Knowledge of Principles Taught in the Laboratory. Mixed Group

0 - 5	10
5 - 10	0
10 - 15	18
15 - 20	5
20 - 25	13
25 - 30	22
30 - 35	11
35 - 40	35
40 - 45	19
45 - 50	27
50 - 55	54
55 - 60	16
60 - 65	63
65 - 70	30
70 - 75	23
75 - 80	46
80 - 85	19
85 - 90	13
90 - 95	1
95 - 100	2

N 427

$\frac{N}{2} = 213.5$

Median = 54.95

S.D. = 21.104

S.D. Median = 1.2763

TABLE IV

Distribution of Scores for Ability to Apply Principles Taught in the Laboratory. Mixed Group

0 - 5	24
5 - 10	17
10 - 15	14
15 - 20	26
20 - 25	24
25 - 30	27
30 - 35	33
35 - 40	30
40 - 45	33
45 - 50	0
50 - 55	31
55 - 60	23
60 - 65	28
65 - 70	25
70 - 75	24
75 - 80	8
80 - 85	18
85 - 90	21
90 - 95	16
95 - 100	5

N 427

$\frac{N}{2} = 213.5$

Median = 42.65

S.D. = 26.52

S.D. Median = 1.6042

TABLE V

Distribution of Scores for Knowledge of Principles Not Taught in the Laboratory. Boys Group

0 - 5	6
5 - 10	5
10 - 15	2
15 - 20	6
20 - 25	4
25 - 30	12
30 - 35	9
35 - 40	21
40 - 45	10
45 - 50	21
50 - 55	37
55 - 60	9
60 - 65	29
65 - 70	14
70 - 75	18
75 - 80	9
80 - 85	24
85 - 90	7
90 - 95	7
95 - 100	0

N 250

$\frac{N}{2} = 125$

Median = 54.53

S.D. = 21.574

S.D. Median = 1.7053

TABLE VI

Distribution of Scores for Knowledge of Principles not Taught in the Laboratory. Girls Group

0 - 5	1
5 - 10	2
10 - 15	1
15 - 20	4
20 - 25	2
25 - 30	8
30 - 35	7
35 - 40	14
40 - 45	8
45 - 50	15
50 - 55	24
55 - 60	9
60 - 65	20
65 - 70	12
70 - 75	16
75 - 80	8
80 - 85	11
85 - 90	8
90 - 95	7
95 - 100	0

N 177

$\frac{N}{2}$ = 88.5

Median = 56.4

S.D. = 20.034

S.D. Median = 1.8819

TABLE VII

Distribution of Scores for Ability to Apply Principles not Taught in the Laboratory. Boys Group

0 - 5	4
5 - 10	2
10 - 15	9
15 - 20	25
20 - 25	20
25 - 30	32
30 - 35	27
35 - 40	24
40 - 45	22
45 - 50	0
50 - 55	23
55 - 60	19
60 - 65	17
65 - 70	11
70 - 75	8
75 - 80	2
80 - 85	4
85 - 90	1
90 - 95	0
95 - 100	0

N 250

$\frac{N}{2}$ = 125

Median = 36.25

S.D. = 18.951

S.D. Median = 1.4981

TABLE VIII

Distribution of Scores for Ability to Apply Principles Not Taught in the Laboratory. Girls Group

0 - 5	7
5 - 10	4
10 - 15	7
15 - 20	20
20 - 25	12
25 - 30	14
30 - 35	29
35 - 40	21
40 - 45	8
45 - 50	0
50 - 55	17
55 - 60	10
60 - 65	16
65 - 70	6
70 - 75	3
75 - 80	2
80 - 85	1
85 - 90	0
90 - 95	0
95 - 100	0

N 177

$\frac{N}{2} = 88.5$

Median = 34.22

S.D. = 18.858

S.D. Median = 1.7710

TABLE IX

Distribution of Scores for Knowledge of Principles Taught in the Laboratory. Boys Group

0 - 5	5
5 - 10	0
10 - 15	10
15 - 20	5
20 - 25	7
25 - 30	13
30 - 35	6
35 - 40	14
40 - 45	14
45 - 50	17
50 - 55	34
55 - 60	10
60 - 65	37
65 - 70	17
70 - 75	10
75 - 80	26
80 - 85	13
85 - 90	10
90 - 95	0
95 - 100	2

N 250

$\frac{N}{2}$ = 125

Median = 55.00

S.D. = 21.148

S.D. Median = 1.6713

TABLE X

Distribution of Scores for Knowledge of Principles Taught in the Laboratory. Girls Group

0 - 5	5
5 - 10	0
10 - 15	8
15 - 20	0
20 - 25	6
25 - 30	9
30 - 35	5
35 - 40	21
40 - 45	5
45 - 50	10
50 - 55	20
55 - 60	6
60 - 65	26
65 - 70	13
70 - 75	13
75 - 80	20
80 - 85	6
85 - 90	3
90 - 95	1
95 - 100	0

N 177

$\frac{N}{2}$ = 88.5

Median = 54.87

S.D. = 21.054

S.D. Median = 1.9777

TABLE XI

Distribution of Scores for Ability to Apply Principles Taught in the Laboratory. Boys Group

0 - 5	15
5 - 10	11
10 - 15	7
15 - 20	14
20 - 25	10
25 - 30	18
30 - 35	16
35 - 40	16
40 - 45	22
45 - 50	0
50 - 55	21
55 - 60	10
60 - 65	18
65 - 70	14
70 - 75	15
75 - 80	7
80 - 85	12
85 - 90	11
90 - 95	9
95 - 100	4

N 250

$\frac{N}{2} = 125$

Median = 44.09

S.D. = 26.675

S.D. Median = 2.1085

TABLE XII

Distribution of Scores for Ability to Apply Principles Taught in the Laboratory. Girls Group.

0 - 5	9
5 - 10	6
10 - 15	7
15 - 20	12
20 - 25	14
25- 30	9
30 - 35	17
35 - 40	14
40 - 45	11
45 - 50	0
50 - 55	10
55 - 60	13
60 - 65	10
65 - 70	11
70 - 75	9
75 - 80	1
80 - 85	6
85 - 90	10
90 - 95	7
95 - 100	1

N 177

$\frac{N}{2} = 88.5$

Median = 40.22

S.D. = 26.321

S.D. Median = 2.4729

TABLE XIII

Summary of Tables I to XII

Mixed Group				Median	S.D.	S.D. Med.
Table I	Non Lab.	Knowledge of Prin.		54.549	20.99	1.2697
Table II	" "	Application of Prin.		36.66	18.79	1.1366
Table III	Lab.	Knowledge of Prin.		54.95	21.10	1.2763
Table IV	Lab.	Application of Prin.		42.65	26.52	1.6042
Mixed or Total Group Separated into Two Divisions--Boys vs. Girls.						
Table V	Non Lab.	Knowledge of Prin.	Boys	54.53	21.57	1.7053
Table VI	" "	" " "	Girls	56.40	20.03	1.8819
Table VII	" "	Application of "	Boys	36.25	18.95	1.4981
Table VIII	" "	" " "	Girls	34.22	18.85	1.7710
Table IX	" "	Knowledge " "	Boys	55.00	21.14	1.6713
Table X	" "	" " "	Girls	54.87	21.05	1.9777
Table XI	" "	Application " "	Boys	44.09	26.67	2.1085
Table XII	" "	" " "	Girls	40.22	26.32	2.4729

Number of Cases Mixed Group	427
Number of Cases Boys Group	250
Number of Cases Girls Group	177

TABLE XIV

A. Standard Deviation difference between
B. Median Differences between
C. Experimental Coefficient between

1. Table I vs. Table III Knowledge of Principles Non Lab. vs. Lab.

   A. S.D. Difference = 1.809

   B. Med. Difference = .401 favor of III Lab. Prin.

   C. Exp. Coef. = .0797

2. Table II vs. IV Ability to Apply Principles Non Lab. vs. Lab.

   A. S.D. Difference = 1.952

   B. Med. Difference = 5.99 favor of IV Lab. App.

   C. Exp. Coef. = 1.1039

3. Table V vs. IX Knowledge of Principles. Non Lab. vs. Lab. Boys

   A. S.D. Difference = 2.39

   B. Med. Difference = .47 favor of Lab. Principles

   C. Exp. Coef. = .0707

4. Table VII vs. XI Ability to Apply Principles. Non Lab. vs. Lab. Boys

   A. S.D. Differences = 2.58

   B. Med. Difference = 7.84 favor of Lab. Prin.

   C. Exp. Coef. = 1.093

5. Table VI vx. X Knowledge of Prin. Non Lab. vs. Lab. Girls

   A. S.D. Differences = 2.72

   B. Med. Difference = 1.53 favor non lab.

   C. Exp. Coef. = .2023

TABLE XIV (Continued)

6. Table VIII vs. XII Ability to Apply Prin. Non Lab vs. Lab. Girls

A. S.D. Difference = 3.03

B. Med. Difference = 6. favor lab. application

C. Exp. Coef. = .7123

7. Table V vs. VI Knowledge of Prin. Non Lab. Boys vs. Girls

A. S.D. Difference = 2.525

B. Med. Difference = 1.97 favor of girls

C. Exp. Coef. = .2806

8. Table VII vs. VIII Ability to Apply Prin. Non Lab. Boys vs. Girls

A. S.D. Difference = 2.30

B. Med. Difference = 2.03 favor of boys

C. Exp. Coef. = .3174

9. Table IX vs. X. Knowledge of Prin. Lab. Boys vs. Girls

A. S.D. Difference = 2.59

B. Med. Difference = .13 favor of boys

C. Exp. Coef. = .018

10. Table XI vs. XII. Ability to Apply Principles Lab. Boys vs. Girls

A. S.D. Difference = 3.24

B. Med. Difference = 3.87 favor of boys

C. Exp. Coef. = .43

CHAPTER VI

SUMMARY OF THE FINDINGS

The writer of this thesis wishes to point out that the following conclusions are drawn from the results obtained from the 427 cases observed in this study in the division of mechanics in physics.

I. There is little or no evidence pointing to any effect of the usual laboratory method having increased the knowledge of principles of the mixed group above that taught in the regular class period.

II. From the results of this study it seems practically certain that the usual laboratory method will produce some increase in the ability of the mixed group to apply the principles of mechanics.

III. There is little or no evidence pointing to any effect of the usual laboratory method having increased the knowledge of principles for either the boys group or the girls group, above that taught in the regular class period.

IV. From the results of this study it seems practically certain that the usual laboratory method will produce some increase in the ability, of the boys group and of the girls group, to apply the principles of mechanics.

V. From the results of this study it seems practically certain that there is no difference in the ability between boys and girls to secure knowledge of physics principles and ability to apply those principles.

VI. Neither the boys' group nor the girls' group showed any tendency to respond more favorably to either type of teaching.

VII. In general, laboratory teaching produces a small increase in the ability of students to apply principles of physics but little or no increase in the knowledge of the principles of physics above that obtained in the regular class work.

APPENDIX

A. Bibliography

B. List of Cities included in this study

C. Sample of the tests and correspondence

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LIST OF TOWNS INCLUDED IN THIS STUDY

1. Hutchinson
2. Ellis
3. Yates Center
4. Olathe
5. Lyons
6. Langdon
7. Peabody
8. Burns
9. Anthony
10. Clay Center
11. Richmond
12. Marysville
13. Phillipsburg
14. Clearwater
15. Abilene
16. Chapman
17. Emmett
18. Florence

Kansas University
Department of Education

Florence, Kans.
November---1926.

Principal of High School:

Under the direction of the School of Education of the University of Kansas, I am making an analytical study of the value of laboratory work in the teaching of physics in high school.

For this purpose I desire to test the results in mechanics of physics in classes of forty or fifty representative Kansas high schools. Since it is impracticable for me to make personal visitations, I shall send the tests, which I wish given, shortly after this amount of work has been completed. The results will not be used to compare the several school systems but rather for the purpose of making comparisons among the different phases in individual papers, and also for collective analysis.

The tests may be given and checked as a regular test by the instructor, if he so desires. Complete directions will accompany the tests. Return postage and tests will be supplied free.

If you will cooperate, please check in the squares the answer appropriate and give the total number enrolled in physics.

(Page 2)

I will give the tests ______	
I shall not be able to give the tests ______	
We have enrolled in physics pupils to the number of ______	
We expect to complete mechanics, as given in Black and Davis, to pages 193 and all relative laboratory work, about ______	
Send the tests to ______	

Thanking you for your kind cooperation, I am

Respectfully yours,

Raymond C. Perrussel

Directions:
To the Teacher:

This test will not be used to compare your class with that of any other school. This study will deal with each individual. An attempt is to be made to determine how much better, if any, pupils learn the principles of physics through the means of laboratory exercises and their ability to apply the principles learned in the laboratory and those learned only in theory. This study will be a comparison of THEORY vs. LABORATORY where all scores will be combined. We are very anxious to have all papers of each student who takes the tests as our conclusions will be based on the averages of the entire group and not on the better papers or the poorer ones.

Allow the pupils as much time as they reasonably need to complete as many of the statements or problems as they can. Before giving the test to the pupils, BE SURE THAT EACH HAS A SHARP PENCIL AND EXTRA PAPER FOR FIGURING. Also, see that each one is seated where he will not be tempted to copy the work of another.

EXPLAIN TO THE PUPILS

1. The tests will be placed face down on the desk of each pupil and they are to fill in the data concerning themselves asked for.
2. When this is done explain that this will be a test given over mechanics and they will be given a reasonable time to finish all of the questions they are able to.
3. Explain that the questions are of two kinds of which the following are examples:

1. North America was discovered by (1) in the year (2) (Enter on the line with the number corresponding to the number in the parenthesis the word, phrase, or number omitted.) (1) Columbus (2) 1492

2. N. America was discovered by (1) Columbus (2) Drake (3) Hoover (4) Fulton (Enter the number of the word, phrase, or number which will make the statement complete and correct on the line opposite the statement. 1

3. In order that all may start the same time, three signals will be given; "Get ready" and each will hold his paper and be ready to turn it quickly; "Pencils up" and each will hold pencil up in the air; "Begin" and each will turn his paper over and begin.

4. Explain that the number completed correct not the number attempted is the basis for scoring the papers.

5. The teacher will answer no questions after the signal to begin has been given.

6. Have each pupil write his name in the bottom left hand corner of the front side of each page of the test.

7. This will be two tests of two pages each. One page of each test deals with knowledge of principles while the second page is the application of the principles.

8. These questions were selected from a large number of standard tests.

Directions: Read each question and select the best answer. Record the number of the best answer on the line at the right as shown in the sample: The most dense of these metals is (1) Iron (2) Mercury (3) Gold (4) Copper (5) Tin 3

1. The measure of the quantity of matter a given body contains is called its (1) density, (2) weight, (3) energy, (4) mass, (5) momentum. ____

2. The attraction between particles of different substances is called (1) capillarity, (2) magnetism, (3) inertia, (4) adhesion, (5) cohesion. ____

3. The measure of the earth's attraction for a body is called (1) velocity, (2) weight, (3) gravitation, (4) mass, (5) magnetism. ____

4. Momentum is measured by the product of two numbers divided by gravity. One of the numbers is mass, the other is (1) distance, (2) force, (3) velocity, (4) acceleration, (5) time. ____

10. The term used to denote the rate of doing work is (1) erg, (2) poundal, (3) power, (4) energy, (5) efficiency. ____

12. The word that describes the energy of a body due to its motion is (1) centripital, (2) potential, (3) curvilinear, (4) kinetic, (5) centrifugal. ____

16. The kinetic theory of matter assumes that the molecules of matter are (1) of the same size (2) composed of two electrons, (3) small magnets, (4) in constant motion, (5) rubber balls. ____

17. As one carries a barometer up a mountain the mercury (1) falls gradually (2) rises gradually, (3) remains stationary, (4) rises rapidly, (5) drops very rapidly. ____

The following statements have words left out where the numbers in parentheses appear. Supply the missing word in the margin on the line whose number corresponds to the numbered parenthesis. 1.____

5. The law of (1) of (2) means that no energy is created and none destroyed. 2.____

6. To every action there is an (3) reaction in the (4) direction

7. Pressure exerted on any part of an enclosed liquid is transmitted (5) in all directions and acts with an (6) force on all (7) surfaces and at right angles to them.

11. The (8) is the absolute unit of force that acting upon (9) of mass will give to it an acceleration of (10) per second per sec.

13. The erg is the work done by a force of (11) acting through a distance of (12)

14. Any two bodies in the universe attract each other with a force which is (13) proportional to the product of the (14) and inversely proportional to the (15)

15. The pressure on the bottom of a vessel is dependent on the (16) and (17) of the liquid and independent of the (18) and (19) of the vessel.

18. The acceleration of a given body is (20) to the (21) causing it.

8. The tendency of a body to retain its condition of rest is (22).

9. The attraction between particles of the same substance is called (23).

3. ____________
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23. ____________

1. A ball with a mass of 1 lb. at N.Y. is taken to Denver. The mass is (1) increased, (2) diminished, (3) not affected, (4) doubled, (5) 1/4 as large. ________

2. The force that holds powdered graphite together in lead for lead pencils is the force of (1) friction, (2) cohesion, (3) gravity, (4) adhesion, (5) gravitation. ________

6. The kick of a rifle may best be explained by (1) Newton's law of interaction (2) Law of gravitation, (3) Hooke's Law, (4) Pascal's law, (5) Law of accelerated motion. ________

7. If the areas of the large and small pistons of a hydraulic press are to each other as 20 to 2, the pressures are to each other as (1) 400 : 1, (2) 10 : 1, (3) 1 : 1, (4) 100 : 1, (5) 40 : 2. ________

8. If a moving train is suddenly stopped the passengers are thrown violently forward. This is best explained by (1) Pascal's principle, (2) Boyles law, (3) inertia, graviation, (5) conservation of energy. ________

3. A certain mass weighs 50 lbs. If the force of gravity was doubled its weight would be ________

4. What force acting on 98 gm. mass whose velocity is 10 cm. per sec. will stop it in 2 seconds? ________

5. A ball with a mass of 1 lb. falls with a velocity of 64 ft. per sec., hits the floor with 64 ft. lbs. of energy, neglecting friction of air, it will rebound to a height of ________

9. The fact that liquids take a spherical form is an illustration of the phenomena of ________

10. If an engine lifts 550 lbs. of rock 500 feet in 5 sec., what horse power is it exerting? ________

11. A mass of 15 gms. has an acceleration of 6 cm. per sec. What force in dynes was required? ________

12. What is the difference in the KE of a pound mass moving at the rate of 500 feet per sec. and the KE of a 500 lb. mass moving at the rate of 1 ft. per sec.? ________

13. A force of 10 dynes acting thru 20 cm. may be expressed as (1) ergs. 1.__________

14. The attraction between the earth and sun is (2) times as great now as if the distance between them was doubled. 2.__________

15. The pressure per sq. fobt in a swimming tank filled with water to a depth of 10 ft. is (3) lbs. per sq. ft. The wt. of a cu. ft. of water is 62.4 lbs. 3.__________

17. In ascending a mountain the mercury drops 2 inches below standard conditions. How high is the mt. above sea level? __________

18. What acceleration will a force of 5 lbs. produce in a body weighing 16 lbs? __________

16. The evaporation of liquids may be attributed to (1) radiation, (2) sublimate, (3) atomic, disintegration, (4) molecular motion, (5) capillarity. __________

Directions: Read each question and place the number of the best answer on the line at the right of the statement.

1. The smallest stress that will cause a permanent set in a body is called (1) elasticity, (2) strain, (3) factor of safety, (4) tortion, (5) elastic limit. ____________

13. The ratio of the change of speed is called (1) velocity, (2) acceleration, (3) distance, (4) gravity, (5) kinetic energy. ____________

14. Sliding friction is proportional to the (1) length of the moving surface, (2) weight of the moving object, (3) Time the objects are in contact (4) temperature of the laboratory, (5) Velocity of the moving object. ____________

15. A body immersed in a liquid is buoyed up by a force equal to (1) The weight of the displaced liquid (2) Volume of the displaced liquid, (3) Pressure on it, (4) The weight of the object (5) Volume of object times its density. ____________

16. The distortion of elastic materials are proportional to (1) Elastic limit (2) Factor of safety, (3) distorting force, (4) cross section, (5) coffecient of friction. ____________

17. The ratio of the useful work done by a machine to the work done on it is commonly called (1) Joules Mechanical equivalent (2) Coefficient of friction, (3) Efficiency, (4) Mechanical advantage, (5) absolute unit of work. ____________

18. The point at which the entire weight of a body is concentrated is called (1) fulcrum, (2) mass, (3) center of gravity, (4) equilibrium, (5) moment. ____________

The following statements have words omitted where the numbers in the parentheses appear. Supply the missing word in the margin on the line whose number corresponds to the numbered parenthesis.

1. ____________

2. ____________

3. ____________

4. ____________

3. The energy of an elevated hammer is an example of (1) energy.

4. If two forces are represented by two adjacent sides of a parallelogram their resultant is represented by the (2).

5. Parallel forces are in equilibrium when the (3) of the opposite forces is zero and the (4) of their moments about a (5) is zero.

6. The mechanical advantage of any lever is the ratio of (6) to (7).

7. For the incline plane the mechanical advantage where the force is applied parallel to the plane is the ratio of the (8) to the (9) of the plane.

8. The mechanical advantage of a system of pulleys provided no energy is (10) inside the pulley is (11) to the number of (12) of the cord supporting the load.

9. The period of a pendulum is directly proportional to the (13).

10. The ratio between the weight of a body and the weight of an (14) (15) of (16) is its specific

11. A barometer is the name of the common instrument for measuring the (17)

12. The temperature remaining the same, the volume of a gas varies (18) as the (19).

19. Density is a term expressing (2) per unit (21).

5. ____________

6. ____________

7. ____________

8. ____________

9. ____________

10. ____________

11. ____________

12. ____________

13. ____________

14. ____________

15. ____________

16. ____________

17. ____________

18. ____________

19. ____________

20. ____________

21. ____________

8. The greatest mechanical advantage which can be obtained by the use of 3 movable pulleys is (1) 6, (2) 7, (3) 8, (4) 3, (5) 5. __________

10. When 100 cc. of ice weigh 92 grams the specific gravity of ice is (1) .92, (2) 1.08, (3) .125, (4) 8, (5) 5. __________

14. A piece of iron weighing 30 lbs. was pulled along on a level oak plank. It requires a pull of 18.6 lbs. to move the iron at uniform speed. The coefficient of friction is therefore (1) 1.61, (2) .486, (3) 11.4, (4) 558, (5) .62. __________

15. The ordinary spring balance is an application of (1) principle of moments, (2) Hooke's Law, (3) Boyles' Law, (4) Composition of forces, (5) Charles' Law. __________

1. The elastic limit of two wires of the same material whose diameter are in the ratio of 1 to 2 respectively will be in the ratio of (1).

5. A and B are holding up a 50 lb. weight on a 25 foot pole. The weight is 5 feet from (A) and 20 feet from B. A is holding (2) lbs. and B is holding (3) lbs.

18. A 10 foot crowbar that weighs 20 lbs. and having the center of its gravity 2 feet from the large end will balance in the center when a 15 lbs. wt. is hung (4) from the small end.

3. If a 50 lb. ball falls 100 feet and all of its energy is transformed into work, how much work will be done? (5)

4. One force of 4 lbs. and a second force of 3 lbs. act at a point, making an angle of 90 degrees with each other. The resultant force is therefore (6)

6. The mechanical advantage of a lever is .8. How long would its resistance arm be if the effort was applied 68 inches from the fulcrum.(7)

1. __________
2. __________
3. __________
4. __________
5. __________
6. __________
7. __________
8. __________
9. __________
10. __________
11. __________
12. __________
13. __________

7. How long must a board be to make an incline plain with a mechanical advantage of 5, when one end is placed on a wagon which is 3.5 feet high. (8). 14. ________

9. A clock loses time. Should the pendulum be lengthened or shortened. (9)

11. A column of mercury is 38 inches high in a barometer. What is the pressure in atmospheres. (10)

12. Under a pressure of 15 lbs. per sq. inch a certain mass of gas has a volume of 100 cu. ft. What volume will the same mass of air have when under a pressure of 300 lbs. (11).

13. What acceleration will cause the velocity of a body to change from 46 ft. per sec. to 88 ft. per sec. in 7 min. (12)

17. What is the efficiency of a machine when a force of 50 lbs. acting through a distance of 30 ft. lifts 200 lbs. 6 feet? (13)

19. What is the density of ice when 100 cc. weigh 92 grams?