1934

A study of high school physics in Porter County, with special emphasis on storage facilities and waste in apparatus

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A STUDY OF HIGH SCHOOL PHYSICS IN PORTER COUNTY, WITH SPECIAL EMPHASIS ON STORAGE FACILITIES AND WASTE IN APPARATUS

by

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Contributions of the Graduate School
Indiana State Teachers College
Number 186

Submitted in Partial Fulfillment
of the Requirements for the
Master of Science Degree
in Education

1934

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to the trustees and physics teachers of Porter County for the kindly cooperation he received while searching through the school records and physics laboratories.

Acknowledgments are also due Dr. J. F. Mackell, Dr. J. R. Shannon, and Mr. W. H. Woodrow for their helpful suggestions, counsel, and criticisms in the preparation of this study.

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I. INTRODUCTION

Physics as a subject of school instruction goes back to the time of the origin of the universities in Western Europe during the twelfth and thirteenth centuries.[1] With the contributions of Galileo in the sixteenth century and of Newton in the seventeenth century, physics became a quantitative subject, and at the same time the establishment of a firm experimental basis for the study of natural phenomena aroused widespread interest in natural philosophy. During the eighteenth century popular lectures and demonstrations were so much in demand that courses in physics came to be offered in the colleges of America. The first high school, that opened in Boston in 1821, included physics in its curriculum. No laboratory work was done, however, for about fifty years. The first university laboratory of physics was opened by the Massachusetts Institute of Technology in 1869 and this was followed in the high schools by the gradual transition of class demonstrations into individual experimentation. By 1872

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[1]Herbert Hazel, "High School Laboratory Work in Physics," School Science and Mathematics, (January, 1933), pp. 53-55.

physics had so progressed that it was made an entrance requirement of Harvard University. This action was soon followed by other universities. There was little uniformity, though, either in content or procedure in the secondary schools where physics was taught.

In 1887 A. P. Gage, physics instructor in the English High School of Boston, and one of the leaders in the introduction of laboratory work in the high school, wrote in the preface of his well known Introduction to Physical Science:[2] "An experience of about six years in requiring individual laboratory work from my pupils has constantly tended to strengthen my convictions that in this way alone can a pupil become a master of the subjects taught."

The greatest single influence in developing laboratory work was the publication in 1886 of the Harvard Descriptive List.[3] This list describing forty experiments to be performed by pupils, provided a criterion in standardizing laboratory equipment and helped to make laboratory procedure more nearly uniform. Between 1886 and 1905 the movement of standardization went too far. Syllabi from the leading universities came to be regarded more and more as ready made courses instead of as suggested guides. More and more emphasis was put on the formal and mathematical side of the subject at the expense

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[2]A. P. Gage, Introduction to Physical Science (Boston: Ginn and Company, 1887), p. iii.

[3]Harvard University, Harvard Descriptive List, 1886.

of the informational and experimental. Physics teaching came to aim more and more at preparation for college and less toward practical usefulness in life. The beginning of the twentieth century marked the first reaction against the emphasis on the formal and disciplinary treatment of physics. This period witnessed the passing of the old dogma of formal discipline, based on the psychological fallacy that the mind is a homogeneous tool which can be sharpened by mathematics, physics, and Latin so that it will cut equally well in all fields. So by 1908 thinking teachers over the country began to take stock of the content and methods in vogue, and attempts were made to reorganize both in the light of the new knowledge of psychology and in the light of the changed character of secondary school population which had been growing all the while by leaps and bounds.

There have always been two distinctly opposed schools of thought in physics, each with its clearly defined creed.[4] The old school holds essentially that physics is the only great quantitative natural science in the high school course, and therefore, it should be treated from the quantitative standpoint in order to give students an appreciation of the value of quantitative knowledge, and to train them in habits of accuracy and of quantitative thinking. The new conception is that

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[4] H. L. Terry, "Physics in the High School," Educational Review, XL (October, 1910) pp. 250-255.

physics is the science of a great group of natural phenomena by which we are surrounded, and that it should be the aim of the high school to bring the student into a knowledge and appreciation of these phenomena, and to give him power to recognize and deal with them under new or unusual conditions in an intelligent manner. This does not imply that physics is not a quantitative science but it does mean that the determination of exact or even approximately exact relation is not within the province of the high school, but belongs to an advanced stage of work based upon a proper understanding of phenomena.

John F. Woodhull, Professor of Physical Science, Teachers College, Columbia University, said: "I cannot agree with those who would restrict physics to the select few who are mathematically inclined and have perhaps a technical course in view. Physics appears to me to be a subject which all pupils need. The community is now demanding it for its children. Teachers of other subjects adapt their instruction to the needs of the majority of their pupils. Physics teachers must do likewise. Let it be conceded that the high school teacher's task for the present is both to fit for college and at the same time to make his physics teaching as good as he can in spite of college requirements."[5]

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[5]John F. Woodhull, Ph. D., The Teaching of Science. (New York: The Macmillan Company, 1918), pp. 14-15.

II. THE PURPOSE AND PROBLEMS OF THIS STUDY

A. The Purpose

It seems certain that the teaching of physics in the secondary schools needs no justification. But several condemnatory statements have been made about this science. Colleges have stated frequently that secondary physics work is not strong and inspection work reveals poor equipment and poor laboratories in many cases. Moreover it has been frequently charged that, because of the cost of laboratory equipment and apparatus, physics is a very expensive subject to include in the secondary school curriculum.

This study was attempted by the writer to determine the existing conditions in the physics laboratories in our secondary schools. Special emphasis has been placed on the expense item, with due consideration given to space provision, physical conditions, etc.

B. The Problems

The proposed investigation of the physics laboratories resolves itself into the following major problems:

1. To determine the amount of physics apparatus purchased as far back as the trustees' records are available. (At least three years.)

2. To find how much of the apparatus has been destroyed or lost.

3. To note condition and amount of apparatus on hand.

4. To check the facilities for storing physics apparatus during both the school term and summer vacation.

5. To determine how the physics laboratories meet the state recommendations.

III. THE DATA AND THE METHOD OF SECURING THE DATA

A. The Data.

1. Sources of the data. The data used in this study were secured from the records on file in the township trustees' offices, from the high school principals' offices, and by visiting the physics departments in the high schools of Porter County. The list of physics apparatus was taken from the official Indiana list of required equipment.[6] The suggestions for proper laboratory construction and equipment were obtained from a bulletin prepared by the State Department of Public Instruction.[7]

2. Means of securing the data. The writer secured almost all of the data personally from the records in the township trustees' offices. These records were sorted and all purchases of physics equipment and apparatus noted. In some of the larger high schools the records were obtained from the heads of the science departments. Records were obtained for at least three years and as far back of that as possible.

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[6] State Department of Public Instruction, Indiana Science Laboratory Equipment Lists (Indianapolis: Wm. B. Burford, Contractor for State Printing and Binding, July, 1924).

[7] State Department of Public Instruction, Division of Inspection, "Laboratory Construction, Equipment, and Exercises for Science Teaching and Laboratory Work", Bulletin Number 65H (Indianapolis: Wm. B. Burford, Contractor for State Printing and Binding, 1926), pp. 7-11, 14-15.

The physics laboratories were then visited and, with the help of the instructor, each item listed was marked either "used or broken," "lost or stolen," or "still in use." The laboratory facilities were also checked, the storage space measured, and the instructors were asked any questions that could not be answered by personal investigation.

3. Reliability of the data. The writer believes that the method just described for securing the data needed in this study is the most reliable that could be used. The other contemplated method was the use of a questionnaire. The two chief objections to the use of a questionnaire are fairly well met in the method used, viz., the small number of responses to questionnaires and the lack of good faith in answering them. Since each township trustee or head of science department had a record of the physics equipment purchased during the period of study, and every science laboratory was thrown open to the writer for inspection, every high school in Porter County which includes physics in its curriculum was included in the study.

IV. SCOPE OF THE STUDY

There are ten commissioned township high schools in Porter County and one city high school. Table I indicates the division of these schools for this study. All of the township high schools include physics in their curriculum but two. One of these, Jackson, has only two years of senior high school, and Kouts (Pleasant Township) has not offered physics for several years. The principal informed the writer, however, that physics would be offered during the following school year (1934-5). Boone Grove High School (Porter Township) substituted physical geography for physics during the school year 1933-4, but this was only a temporary change in the program. In all, data from nine schools were used in the study. Since the enrollment of these schools varied from fifty to six hundred eighteen they should represent in size the majority of Indiana high schools.

TABLE I

Division of Porter County High Schools Used in Study

Township	Name of High School	Enroll-ment	Frequency of Offering Physics	Approximate Size of Class	Included in Study
Boone	Hebron	77	Every other year	16	Yes
Center	Valparaiso#	618	Annually	25	Yes
Jackson	Jackson##	24	Physics not offered		No
Liberty	Liberty	66	Every other year	14	Yes
Morgan	Morgan	73	Annually	8	Yes
Pine	No high school				
Pleasant	Kouts	106	Physics not offered###		No
Portage	Portage	92	Annually	12	Yes
Porter	Boone Grove	79	Annually####	11	Yes
Union	Wheeler	71	Annually	8	Yes
Washington	Washington	50	Annually	8	Yes
Westchester	Chesterton	278	Annually	25	Yes

#Valparaiso is a city high school.

##Jackson maintains no eleventh and twelfth year.

###Physics to be offered beginning 1934.

####Physical geography substituted for physics, 1933.

V. THE IMPORTANCE OF A PHYSICS LABORATORY AND TRENDS IN SPACE PROVISION

A. The Importance Of A Physics Laboratory

One of the most fundamental objections to much of our science work consists in the practice of substituting a textbook for laboratory work. In many cases it consists in the belief that the textbook may be substituted for laboratory experiments. Since science has to do with the material and material forces of the world, the content is thus such that textbooks must fail to impart the real spirit of this subject.

Through wisely chosen laboratory exercises and efficient laboratory administration, science teaching accomplishes its notable part in school instruction. Without its experimental aspects science teaching when attempted is largely shorn of its distinctive features and educational possibilities.[7] Through laboratory exercises there can be developed, and directed, a desire on the part of the pupil to learn. Science studies without laboratory exercises are scarcely worth the name. Laboratory exercises are not only a means for first-hand information, concerning facts which are fundamental in the discussion of topics, but in addition they should be thought-provoking. The facts in themselves are not enough. There must

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[7] H. Brownell, and F. B. Wade, The Teaching of Science and The Science Teacher, (New York: The Century Co., 1925), pp. 3-6.

be apparent to pupils certain relationships between these facts as they note the results of the experiments being performed. There must be such a continuity in these relationships as shall constitute a well-defined thought process, natural and progressive, even when an introductory course in the secondary school.

Facts learned through wisely-chosen laboratory exercises have with beginners in science a value in mental processes not possible for information gained from formal statements of text and reference books. The former type of work exceeds in worth the latter in that it is better comprehended and related, and it is more likely to be remembered. When enough of these laboratory exercises have been performed, pupils are mentally equipped for the more rapid interpretation and assimilation of facts as summed up in books wherein the experiences of others are set forth. The attention of pupils having been centered upon a topic, and their interest aroused by laboratory contact with certain of its phases, it may be confidently expected that to some degree at least there has been developed a desire for further knowledge concerning the topic.

There has been raging for the past few years quite a controversy between school men over lecture-demonstration method and the individual laboratory method. There have been more than a dozen experimental studies made on this particular matter of determining whether or not the extensive and expensive use of the laboratory in secondary school science is justified. The use of the lecture-demonstration has been thought by a good many to be equal to, if not superior to individual laboratory work, besides being much more economical of time and expense.

The gist of the findings from these experimental studies seem to support these contentions.

Many teachers of science, however, are not convinced and are unwilling to admit that the mainstay of instruction in science as opposed to other fields, the laboratory method, should be done away with. In a paper read before the Physics Section of the Central Association of Science and Mathematics Teachers, in Chicago in 1929, H. C. Krenerick said, "I have no patience with those individuals who claim that the laboratory is not necessary, that the lecture-demonstration method better prepares the student and give as their proof that the student can write a better examination. I would be very much surprised if he could not, for with that method much more time must be available for drill and problem work. Why not be consistent and omit the demonstration? With the extra time in drill he would be able to write a still better examination.

"The controversy is purely a question of why we are teaching physics. If it is to acquire a certain number of scientific facts, use the lecture-demonstration method. Physics with its laboratory possibilities offers to the student a type of information and experience which is of far greater value to him than the ability to write a good examination, a training not found in any other subject. These tests that are being made in the lecture-demonstration method do not and cannot prove anything because they test only the lecture-demonstration class of accomplishments."[8]

Herbert Hazel, of Bloomington, Indiana, sizes up the controversy quite well in his article, "High School Laboratory Work in Physics,"[9] as follows: "Many of the investigations into the lecture-demonstration and individual laboratory methods were made without isolation of the variable factors. Such isolation, difficult as it is when human elements are involved, is a prime requisite for any experimental study. Others studied the learning under different laboratory processes as carefully as the uncertainty and the elusive character of measuring human achievement would permit. A point which has not always been recognized in drawing conclusions, however, is that an apparent superiority of one method over the other does not mean necessarily that one should replace the other in its entirety. I am certain that in our zeal for individual laboratory work following its introduction fifty years ago, we have carried into that phase of the work much material which properly belongs in the lecture-demonstration phase. This being the case, we need a wiser distribution of materials between the two phases rather than an abandonment of one in favor of the other, one should remember that historically the lecture-demonstration method is much the

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[8]H. C. Krenerick, "Laboratory Methods and Experiments in Physics," School Science and Mathematics, (January, 1930), p. 38.

[9]Herbert Hazel, "High School Laboratory Work in Physics," School Science and Mathematics, (January, 1933), p. 60.

older, that it has been tried thoroughly and that fifty years ago it was found very desirable to give considerable emphasis to a supplementary approach through the individual laboratory method. In my judgment the pendulum has just swung too far, and now we need to take stock again of the materials which lend themselves to more effective study one way or the other and wisely select and distribute the subject matter of both. The project method and the demonstration method both have great merit, but they should supplement and not displace, the individual laboratory study of a central core of experiments which cover an extended range of the subject.

"The laboratory has ceased to be a place where pupils verify laws, but it is still a place for students to get concrete sensory experience. The 'feel' of the apparatus, its set up, its adjustment and manipulation, the gathering and recording of experimental data and their association, properly drawn, constitute a sensory experience which gives meaning and reality to the principles involved. Particularly in those portions of the work in which the pupils' background of experience is meagre, this concrete approach is indispensable."

B. Trends In Space Provision

With the steadily increasing high school enrollment of the past twenty years has come an increasing demand for more and better buildings. Changes in organization and curricula have necessitated many changes in building plans. The most significant development revealed in the study of classrooms, science rooms, library, auditorium, and study rooms, made by A. L. Spohn[10] of the Hammond High School, Hammond, Indiana, is a trend away from separate laboratories for the specialized subjects. This trend indicates a growing preference for science work of a general nature rather than the intensive study of separate, highly specialized fields.

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[10]Prof. A. L. Spohn, "Trends in Space Provision in Plans for High School Buildings," School Review, Vol. 38, (1930), pp. 48-49.

VI. THE PHYSICS LABORATORY

A. Outstanding Needs in Physics

Physics is the most extensively taught science in the high schools of the state. Since it has such wide usage and since it is the favorite junior-year and senior-year science, it should have special attention. Its equipment is very expensive and very few pupils actually have an opportunity to do laboratory work. This subject and its teaching should for these reasons be given special attention.

For Indiana high schools the following are the outstanding needs in physics:[11]

1. More equipment, home-made or otherwise, for the use of the pupils.

2. Relatively speaking, less of the show type of demonstration apparatus, which type is wholly relegated to the use of the instructor, is needed.

3. Laboratory table space should be supplied for every pupil in the physics class.

4. Electric outlets should be provided under each table. In addition to a current tap, there should be two gas outlets on each table. Water supply for the individual tables is convenient, but can be dispensed with. There should be running water and at

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[11] State Dept. of Public Instruction, Laboratory Construction, Equipment, And Exercises for Science Teaching and Laboratory Work (Indianapolis: Wm. B. Burford, Contractor for State Printing and Binding, 1926), pp. 14-15.

least one sink installed in the laboratory.

5. Apparatus cases and plenty of drawer space are indispensable. Many schools are comparable to vaultless banks in the matter of cases. Cases should be supplied with doors and locks.

6. An instructor's table with gas, water and electric current should be supplied. This table desk should be 34 inches high. The rear of the desk should have ample cupboard and drawer space.

7. A dark room and a small storage room combined should be found in connection with the laboratory.

One of the outstanding needs of the small high school is a combined laboratory and classroom which will adequately provide for the science offered in these schools and at the same time be so arranged that it may be used for other classwork such as mathematics, history, etc. In searching for a type of installation adapted to the needs of the small high school, a group headed by J. H. Jensen,[12] Head of Department of Science, Northern Normal and Industrial School, Aberdeen, South Dakota, concluded after extensive investigation to use a T type of installation.

Briefly summarized, the combination laboratory and classroom offers the following advantages:

1. It provides a flexible arrangement of the science room to take care of classes from six pupils up to twenty-four pupils in a given science.

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[12]J. H. Jenson, "Classroom Plans for the Teaching of Science in the Small High School"--Abstract, National Education Association, 1928, pp. 579-580.

2. It meets the needs of the small classes and also makes adequate provision for economical expansion in the future.

3. It furnishes a plan for high schools without water, sewer, or gas connections such that these connections may be added later.

4. It offers a science room for the small high school that can teach only one science and provides a room that may be used for other classes as mathematics, history, etc.

5. It provides for a greater percentage of use of the floor space than is now possible in the usual science installation.

6. It makes possible the installation of the necessary furniture for a class of six pupils and also makes provision for increasing the room capacity up to a maximum of twenty-four pupils.

7. It can be used for any teaching combination that the science instructor may be called upon to handle in the small high school.

8. It provides such an arrangement that the pupils may work in groups of four, two, or individually, depending upon the equipment available or the requirement of a particular experiment.

9. It provides a room for a three-year or four-year science sequence with ample storage space for the items commonly used in these subjects.

10. It is possible to shift from class to laboratory work with the least confusion and loss of time. It furnishes a plan whereby the essential furniture for the classroom and stockroom

may be installed with provisions made to add the desirable or necessary equipment as the science work expands.

11. It furnishes an ideal arrangement for supervised study, or for work in science based on the contract plan or unit plan.

12. It provides a common storeroom for all science equipment.

B. Equipping the Physics Laboratory

1. Space devoted to physics laboratories. For the teaching of physics by proper methods a good laboratory is a necessity. The character of the desks and the arrangement for seating and lighting of an ordinary class room are entirely inadequate and should be used only when absolutely necessary. A good laboratory is one with good lighting, ample space for comfortable work, and sufficient space for storing equipment.

The new trend is to use the combination laboratory which serves for more than one science and for lecture room as well.

The laboratories studied varied in size from 18 feet by 20 feet to 24 feet by 30 feet. They were all combination class and laboratory rooms with the exception of one school which had the classroom downstairs and the laboratory upstairs.

The combined laboratory-demonstration and recitation room has educational advantages of much merit. The instructor may stop the individual experimental work when he finds it advisable and can assemble his class for instructions or for demonstrations. He may assemble his class for a short recitation at the beginning of the laboratory period, and he may use the last part of the period for laboratory. He has space available where the more rapid workers who have finished their experiments may work on their written reports or study, out of the way of the others who are still working on their experiments.

2. Electric wiring, gas fixtures, and water. Every physics laboratory should be supplied with electricity and water. It is also convenient to have gas, but until recently, that has been impossible in the majority of township schools. However, compressed gas is now available for the laboratories that are not supplied with natural or artificial gas. Each laboratory table should have several electric outlets. It is convenient to have running water in the center of the laboratory table, but one or two sinks at the side of the room is sufficient. The demonstration table should have water, gas, and electric outlets.

TABLE II

Electric Wiring Of Physics Laboratories

Number of Outlets	Number of Schools
1-3	0
4-8	5
9-12	0
13-16	1
17-20	2
21-24	0
25-28	1

Table II shows the number of electric outlets in the laboratories. All of the schools used in the study had electricity. The outlets varied from four to twenty-six.

TABLE III

Sources Of Heat For Physics Experiments

Sources of Heat	Number of Schools
Gas	2
Electricity	2
Other sources	5

TABLE IV

Water Supply Of Physics Laboratories

Description	Number of Schools
Running water	9
Water from wells	6
Water from city supply	3
Hot and cold water	6
Water at laboratory tables	4
Water at demonstration tables	4
Water at sink	5

Table III shows the sources of heat used in physics experiments. Two schools used gas, two used electricity, and five used other methods of heating, mostly blow torches.

Table IV shows the water supply of the physics laboratories. All of the laboratories had running water. The schools that had no city water had electric pumps and pressure tanks. All of the laboratories had water either at the laboratory tables, the demonstration desk or at the side of the room.

3. Laboratory tables. Laboratory table space should be supplied for every pupil in the physics class. The requirements for a good physics table for students' use are as follows: The top is 42 inches by 72 inches and is built up of maple, ash or other hard wood. It should be acid-proofed. The standard height is 30 inches. The legs should be 3½ inches or 4 inches square, and mortise and tenon construction should be used in rails and legs. The table should have two drawers on each side, each about 20 inches by 17 inches by 4 inches deep. Metal uprights are essential, and the lower cross bar adjustable in height.[13]

If the building is wired with lighting current, outlets should be provided under each table. In addition, there should be two gas outlets on each table. Water supply for the individual tables is convenient, but can be dispensed with.

Table V shows that most of the laboratory tables are of

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[13] State Department of Public Instruction, "Laboratory Construction, Equipment, and Exercises," Bulletin Number 65 H, (Indianapolis; Indiana: Wm. B. Burford, 1926), p. 15.

standard size. Most of these had uprights, some of metal and some of wood. Only one laboratory in the county had a water supply for the individual tables.

TABLE V

Size Of Laboratory Tables

Size of Table	Number of Tables
42" x 72"	35
36" x 60"	1
36" x 120"	1
24" x 240"	1
36" x 240"	1
42" x 144"	1

C. Facilities For Storing Physics Equipment

The rooms of a science department should be grouped, centering preferably around supply rooms. There should be direct access from the supply room to each of the other rooms. It should never be necessary to go out into a corridor to get into another science room. Valuable time is wasted in carrying apparatus back and forth, and none know better than science teachers, themselves, how many such trips there are. If made often during class and laboratory periods, room control and class interest are both risked by these absences of the instructor.[14]

The provision for general storage rooms showed a decrease from 1917 to 1927. Rooms for specific kinds of stores and supplies were provided instead, such as store and apparatus room for gymnasium, kitchen supply room, sewing storeroom, physics storeroom, book storage room, art storeroom, and music storeroom. Changes in classroom methods and materials, which mark the passing of the conventional recitation, and the development of an enriched curriculum necessitate specific space provision for the various kinds of supplies and materials used in the different types of work.[15]

To keep the physics equipment in good condition, it is necessary to have ample storage space. Every laboratory should have a storeroom and several built-in cases. The doors of these cases should have good locks. Some of the cases should have glass doors for display purposes.

Table VI gives the number of storerooms and wall cases in each laboratory. Only three schools in the county had physics storerooms. The number of wall cases varied from one to four.

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[14]H. Brownell and F. B. Wade, _The Teaching of Science and the Science Teacher_, (N. Y.: The Century Co., 1923), p. 35.

[15]Prof. A. L. Spohn, "Trends in Space Provisions and Plans for High School Buildings," _School Review_, Vol. 38, (January, 1930).

TABLE VI

Number Of Physics Storerooms And Wall Cases

Number of Storerooms	Number of Schools	Number of Wall Cases	Number of Schools
0	6	1	2
1	2	2	3
2	1	3	2
		4	2

TABLE VII

Total Amount Of Storage Space

School	Cubic Feet of Storage Space
A	78
B	5592
C	126
D	136
E	1892
F	66
G	2220
H	156
I	337

Table VII shows the total number of cubic feet of storage space available in each laboratory. This includes storerooms and wall cases. The schools are indicated by letter instead of by name. The total amount of storage space varied from 66 cubic feet to 5592 cubic feet.

VII. PHYSICS EQUIPMENT

A. Individual Equipment.

The child in search for solution of his own problems is stimulated to learn by doing. In experimentation he learns to recognize defects and errors, and discovers what constitutes proof. He becomes accustomed to expressing his observations and results of his experiments in accurate English statements. He also learns to cooperate with others and to direct and control himself in specific undertakings.

The increase in population and the keen competition of making a living place increased emphasis upon individual thinking.

Good work in physics has been done with few facilities, but under great difficulties. The ideal laboratory provides an opportunity for the development of individual thinking. The student should be independent, as far as possible, of the teacher's aid in securing materials and in doing work. He should be able to work his own problems without being hindered or helped by his teacher or classmates.

The average laboratory is very poorly provided with sufficient individual equipment and most of the work has to be done at the teacher's desk or demonstration table.

Laboratory work presupposes student participation in that work. In practically no case should more than two students work together. In by far the greater part of the laboratory exercises, individual work should be required. Student participation in laboratory work presupposes several things. Some of these are:[16] (a) Assignments of duties need to be made definitely. (b) Every science pupil must own a definite group of supplies. Pencil, drawing pencil, pen and ink, ruler, notebook, carefully prepared laboratory outline, permanent notebook back with fillers. These are just as much a part of the pupil's equipment as the textbook. (c) The laboratory should be so organized that everyone is engaged at once on entering the laboratory. (d) The teacher should anticipate the lesson and have laboratory directions as well as laboratory supplies ready. (e) The school must furnish an adequate supply of essential laboratory materials, if the science program is to succeed. (f) The teacher must see that all can read laboratory directions. (g) The teacher should be watchful after a proper understanding is so obtained by the class, but, above all things else, he should keep out of the way of the class. (h) The teacher should watch "how" results are obtained as well as to watch "what" results are obtained. When the "how" is considered, fairly large errors may be preferable to very accurate results obtained by poor or vicious methods. Honesty is above par in science. (i) The teacher should see that results are carefully

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[16]E. E. Ramsey, Chairman of Course of Study, "State Course of Study for Secondary Schools," Bulletin Number 65-C, (Indianapolis, Indiana: State Department of Public Instruction, 1923), p. 128.

interpreted and just as carefully stated. Hence, the science teacher can do his bit in English. (j) The teacher should see that the experiment--its materials, manipulations, results, and interpretations--is faithfully put in permanent form. (k) The teacher in a quiz should see that the experiment and its results are related to the text matter or to the outside world. The latter makes science practical; the former should train inductively in the understanding of the principles underlying science.

Table VIII shows the distribution of individual equipment in the high schools used in the study. The schools are listed by letter instead of by name.

The per cents of the required individual apparatus on hand in the various physics laboratories are shown in Table IX. The letters refer to the same schools as in Table VIII. The lowest school had 33 per cent of the required equipment on hand and the highest school averaged 300 per cent.

TABLE VIII

Amount Of Individual Apparatus In Physics Laboratories Used In Study

Description	Quantity Recommended#	Quantity on Hand									
		A	B	C	D	E	F	G	H	I	Average
Micrometer caliper	1	1	2	1	0	2	1	1	1	1	1.11
Vernier caliper	1	1	2	1	1	2	1	1	1	1	1.22
Meter sticks	6	6	12	6	4	12	5	7	8	10	7.78
Steel rod	1	1	3	1	1	2	1	1	2	2	1.56
Mirror scales & supports	4	1	8	1	0	4	1	1	1	1	2.00
Spring & weight holders	4	4	12	2	2	12	4	4	6	8	6.00
Balls, iron	12	4	12	4	3	12	5	4	6	3	5.89
Balls, wood	12	5	18	4	2	12	6	6	3	9	7.22
Balls, lead	12	2	12	2	1	10	5	4	2	5	4.78
Balls, steel	6	4	12	3	2	8	5	3	4	6	5.22
Composition of force board	1	0	2	0	0	1	0	0	1	1	.56
Demonstration balances	6	3	12	3	1	6	4	4	3	5	4.56
Supports	2	0	4	1	0	2	1	1	1	2	1.33
Lever knife edge clamps	4	0	4	0	0	4	0	0	0	2	1.11
Pulleys, single	2	3	6	2	1	4	3	2	2	4	3.00
Pulleys, triple	3	1	5	1	0	3	1	1	2	3	1.89
Inclined plane units	4	1	4	1	0	2	1	1	1	2	1.44

TABLE VIII. (Continued)

Inclined planes	5	0	5	1	0	3	0	0	0	2	1.22
Hall's carriage	4	1	4	1	0	2	1	1	1	2	1.44
Supports	1	1	4	1	0	2	1	1	1	2	1.44
Boyle's law apparatus	1	1	2	1	0	2	1	1	1	1	1.11
Hydrometer jars	3	1	6	1	1	4	2	2	1	2	2.22
Overflow can	1	1	2	1	0	2	1	1	1	1	1.11
Aluminum cylinder with hook	1	0	2	0	0	1	0	1	0	1	.56
Battery jars	8	4	12	2	1	10	4	5	3	8	5.44
Linear expansion apparatus	1	1	1	1	0	1	1	1	1	1	.89
Air thermometer	1	1	2	1	0	2	1	1	1	1	1.11
Steam generator	1	2	8	2	1	6	2	2	2	4	3.22
Water trap	1	0	1	0	0	1	0	0	0	1	.33
Mechanical equivalent of heat tubes	5	1	5	2	1	5	2	2	2	4	2.67
Brass cylinder with glass cover	1	1	2	0	0	1	0	1	1	1	.78
Calorimeter	1	1	4	0	0	1	1	1	1	1	1.11
Dew-point apparatus	1	1	2	1	0	2	1	1	2	1	1.22
Soft iron rods	6	2	6	3	1	6	2	2	1	3	2.89
Soft iron horseshoe core	1	1	2	1	0	1	1	1	1	2	1.11
Bar magnets	6	4	12	4	2	6	4	4	6	6	5.33
U-magnets	6	5	12	4	2	6	4	5	6	6	5.56
Shaker for filings	1	1	2	1	1	2	1	1	1	2	1.33

TABLE VIII. (Continued)

Compassés	8	4	10	2	1	8	4	3	4	6	4.67
Glass friction rods	6	5	12	3	2	6	4	3	4	6	5.00
Vulcanite friction rods	5	3	10	2	1	5	2	2	2	4	3.44
Silk pad	1	2	4	2	1	2	1	2	2	2	2.00
Flannel pad	1	3	6	2	1	4	2	3	3	4	3.11
Condenser plates	2	2	8	2	0	4	2	2	2	4	2.88
Electroscope	1	2	6	2	1	4	2	2	4	4	3.00
Demonstration students' battery	6	4	12	4	1	6	5	3	3	6	4.89
St. Louis motor	1	1	2	1	0	2	1	1	1	1	1.11
Electromagnet attachment for St. Louis motor	1	1	2	1	0	2	1	1	1	1	1.11
Galvanoscope	1	1	6	1	1	2	1	1	2	4	2.11
Galvanometer	1	2	6	1	0	2	1	1	2	2	1.89
Resistance box	1	1	4	1	0	2	1	1	1	2	1.44
Wheatstone bridge	1	2	6	2	1	4	2	2	4	6	3.22
Resistance board	1	1	4	1	0	2	1	1	0	2	1.33
Resistance coils	4	2	8	2	0	6	2	3	2	4	3.22
Commutator	1	1	6	1	0	4	1	1	2	2	2.00
Electric bell	1	3	12	3	1	6	3	2	6	6	4.67
Push button	2	3	8	3	1	6	2	2	3	4	3.56
Voltmeter	1	1	4	1	0	2	1	1	2	1	1.44
Ammeter	1	1	4	1	0	2	1	1	2	1	1.44
Tuning forks	9	4	14	4	2	9	4	3	5	6	5.67

TABLE VIII. (Continued)

Glass resonance tube	1	1	4	1	0	2	1	1	1	1	1.33
Lenses	18	8	18	10	2	14	6	6	6	8	8.67
Prisms	6	6	12	6	2	6	4	4	6	6	5.78
Mirrors	4	5	8	4	2	6	4	4	5	5	4.78
Candle holders & bench supports	2	2	6	2	0	4	1	1	2	2	2.22
Photometer box	1	1	4	1	0	2	1	1	1	1	1.33
Lens support	1	1	4	4	0	2	1	1	1	2	1.78
Mirror support	1	0	5	0	0	3	1	1	0	2	1.33
Object & marker	1	0	4	1	0	2	0	1	1	1	1.11
Screen support	1	1	4	1	0	2	1	1	1	2	1.44
Screen	1	1	4	1	0	2	1	1	1	2	1.44
Balance	1	2	4	2	1	3	2	2	2	2	2.22
Spring balances	13	4	15	6	2	13	8	6	6	8	7.55
Weight sets	2	2	4	2	1	3	2	2	2	2	2.44
Block for weights	1	2	4	2	1	3	2	2	2	2	2.22
Graduated cylinder	1	2	6	2	1	4	2	2	2	2	2.55
Alcohol lamp	1	4	##	2	2	8	6	4	4	##	4.29
Ring & clamp	1	4	12	4	2	6	3	4	4	5	4.89
Thermometers	10	6	20	6	2	10	6	4	6	8	7.56
Lbs. of iron metal filings	1	1	3	1	½	2	1	1	½	1	1.11

#Recommended by State Department of Public Instruction.

##These schools have gas.

TABLE IX

Per Cent Of Required Individual Apparatus

In The Laboratories Used In Study

Description	Per Cent of Required Apparatus								
	A	B	C	D	E	F	G	H	I
Micrometer caliper	100	200	100	0	200	100	100	100	100
Vernier caliper	100	200	100	100	200	100	100	100	100
Meter sticks	100	200	100	67	200	83	117	133	167
Steel rod	100	300	100	100	200	100	100	200	200
Mirror scales and supports	25	200	25	0	100	25	25	25	25
Spring and weight holders	100	300	50	50	300	100	100	150	200
Balls, iron	33	100	33	25	100	42	33	50	25
Balls, wood	42	150	33	17	100	50	50	25	75
Balls, lead	17	100	17	9	83	42	33	17	42
Balls, steel	67	200	50	33	133	83	50	67	100
Composition of force board	0	200	0	0	100	0	0	100	100
Demonstration balance	50	200	50	17	100	67	67	50	83
Supports	0	200	50	0	100	50	50	50	100
Lever knife edge clamps	0	100	0	0	100	0	0	0	50
Pulleys, single	150	300	100	50	200	150	100	100	200
Pulleys, triple	33	167	33	0	100	33	33	67	100
Inclined plane units	25	100	25	0	50	25	25	25	50

TABLE IX. (Continued)

Inclined planes	0	100	20	0	60	0	0	0	40
Hall's carriage	25	100	25	0	50	25	25	25	50
Supports	100	400	100	0	200	100	100	100	200
Boyle's law apparatus	100	200	100	0	200	100	100	100	100
Hydrometer jars	33	200	33	33	133	67	67	33	67
Overflow can	100	200	100	0	200	100	100	100	100
Aluminum cylinder with hook	0	200	0	0	100	0	100	0	100
Battery jars	50	150	25	13	125	50	63	38	100
Linear expansion apparatus	100	100	100	0	100	100	100	100	100
Air thermometer	100	200	100	0	200	100	100	100	100
Steam generator	200	800	200	100	600	200	200	200	400
Water trap	0	100	0	0	100	0	0	0	100
Mechanical equivalent of heat tubes	20	100	40	20	100	40	40	40	80
Brass cylinder with glass cover	100	200	0	0	100	0	100	100	100
Calorimeter	100	400	0	0	100	100	100	100	100
Dew-point apparatus	100	200	100	0	200	100	100	200	100
Soft iron rods	33	100	50	17	100	33	33	17	33
Soft iron horseshoe core	100	200	100	0	100	100	100	100	200
Bar magnets	67	200	67	33	100	67	67	100	100
U-magnets	67	200	67	33	100	67	83	100	100
Shaker for filings	100	200	100	100	200	100	100	100	200

TABLE IX. (Continued)

Compasses	50	125	25	12	100	50	37	50	75
Glass friction rods	83	200	50	33	100	67	50	67	100
Vulcanite friction rods	60	200	40	20	100	40	40	40	80
Silk pad	200	400	200	100	200	100	200	200	200
Flannel pad	300	600	200	100	400	200	300	300	400
Condenser plates	100	400	100	0	200	100	100	100	200
Electroscope	200	600	200	100	400	200	200	400	400
Demonstration students' battery	67	200	67	17	100	83	50	50	100
St. Louis motor	100	200	100	0	200	100	100	100	100
Electromagnet attachment for St. Louis motor	100	200	100	0	200	100	100	100	100
Galvanoscope	100	600	100	100	200	100	100	200	400
Galvanometer	200	600	100	0	200	100	100	200	200
Resistance box	100	400	100	0	200	100	100	100	200
Wheatstone bridge	200	600	200	100	400	200	200	400	600
Resistance board	100	400	100	0	200	100	100	0	200
Resistance coils	50	200	50	0	150	50	75	50	100
Commutator	100	600	100	0	400	100	100	200	200
Electric bell	300	1200	300	100	600	300	200	600	600
Push button	150	400	150	50	300	200	200	150	200
Voltmeter	100	400	100	0	200	100	100	200	100
Ammeter	100	400	100	0	200	100	100	200	100
Tuning forks	45	55	45	22	100	45	33	56	67

TABLE IX. (Continued)

Glass resonance tube	100	400	100	0	200	100	100	100	100
Lenses	45	100	56	11	78	33	33	33	45
Prisms	100	200	100	33	100	67	67	100	100
Mirrors	125	200	100	50	150	100	100	125	125
Candle holders & bench supports	100	300	100	0	200	50	50	100	100
Photometer box	100	400	100	0	200	100	100	100	100
Lens support	100	400	400	0	200	100	100	100	200
Mirror support	0	500	0	0	300	100	100	0	200
Object & marker	0	400	100	0	200	0	100	100	100
Screen support	100	400	100	0	200	100	100	100	200
Screen	100	400	100	0	200	100	100	100	200
Balance	200	400	200	100	300	200	200	200	200
Spring balance	31	116	46	15	100	62	46	46	62
Weight sets	100	200	100	50	150	100	100	100	100
Block for weights	200	400	100	50	150	100	100	100	100
Graduated cylinder	200	600	200	100	400	200	200	200	200
Alcohol lamp	400	#	200	200	800	600	400	400	#
Ring & clamp	400	1200	400	200	600	300	400	400	500
Thermometers	60	200	60	20	100	60	40	60	80
Lbs. of iron metal filings	100	300	100	50	200	100	100	50	100
Average	96	300	92	33	180	95	97	111	147

#These schools have gas.

B. Demonstration Equipment

We need demonstrations in physics in order to arouse interest in the subject. Our laboratory experiments are necessarily restricted to the quantitative aspects of the subject which lend themselves to measurement. But there are many other topics which, while we may not yet be able to measure them, we should like to illustrate in a concrete form by means of an experiment. Surely the experience of all of us lead us to believe that our classes never tire of seeing good demonstrations. We also find that the classroom demonstration helps enormously to make things clear. The concepts in physics are sometimes so difficult for the young to grasp, and often even for the older students, that we need to employ every means available to help them visualize the ideas involved. The demonstration experiment is also a great conserver of time. The teacher can review many topics by performing the right kind of demonstrations followed up by searching questions which are often suggested by the students themselves.

In recent years our attention has been called again and again through various investigations to the undoubted educational value of class experiments. In our enthusiasm some years ago for laboratory experiments we doubtless swung too far to that side and neglected the older form of instruction, namely, lecture-table demonstrations. Today we are swinging back, and probably our demonstrations are less formal than they used to be and more in the nature of a cooperative enterprise between teacher and class. We need more and better demonstrations in physics.

If these demonstrations in physics are so necessary to arouse the interest of the class, to clear up the difficult things, and to save the time of the class and the instructor, why do we not do more of them? I think any inspector of physics teaching in our schools at large will agree that this phase of our teaching today is sorely neglected. In the first place if you look at the equipment of the smaller high schools, and of some large schools, too, you will find a lamentable lack of suitable apparatus and equipment for demonstrations in physics. Many pieces of the older apparatus are merely toys, and these often are out of repair and do not work. Then too, the apparatus is often so flimsy that even when it is in repair it needs many apologies from the teacher. The apparatus is often so small that the pupils in the back seats do not see what is really happening. We should try to get the apparatus makers and dealers to give us better, bigger, and simpler demonstration apparatus.

This crying need for better demonstrations demands first of all a campaign of cleaning up and repairing whatever apparatus we now have that is still good, and of scrapping the rest.[17]

In order to have good demonstrations every physics laboratory should have an instructor's demonstration table. This table should be equipped with gas (or some source of heat),

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[17]N. Henry Black, "Better Demonstrations in Physics," School Science and Mathematics, Vol. 30, (April, 1930), pp. 366-367.

electricity, and running water. The table should be raised so that the demonstrations can be seen from all parts of the room. The rear of the table should have ample cupboard and drawer space.

Table X gives the number of laboratories having a teacher's demonstration table. Only four of the nine laboratories studied had teacher's demonstration tables. Of these, only three had running water, electricity, and a source of heat.

TABLE X

Teacher's Demonstration Tables

Demonstration Tables	Number of Schools
With water, electricity and a source of heat...........................	3
Without water, electricity and a source of heat...........................	1
No demonstration tables........................	5

The amount of demonstration apparatus on hand in the physics laboratories is shown in Table XI, compared with the amount recommended by the State Department of Education. The schools are again represented by letter instead of by name.

Table XII gives the per cent of the recommended demonstration apparatus in the physics laboratories. The percentage ran much lower for demonstration apparatus than for individual apparatus. One school had only 23 per cent of the apparatus recommended and the highest had 118 per cent.

TABLE XI

Amount Of Demonstration Apparatus In Physics Laboratories Used In Study

Description	Quantity Recom-mended	Quantity on Hand									
		A	B	C	D	E	F	G	H	I	Average
Prs. of adhesion discs	1	1	2	1	1	1	1	1	2	1	1.22
Prs. of cohesion plates	1	0	1	0	0	1	1	0	0	1	.44
Wire testing apparatus	1	0	1	0	0	1	0	0	0	0	.22
Wheel & axle	1	0	1	1	0	1	0	1	0	1	.56
Stop watch	1	1	3	1	1	1	1	1	1	1	1.22
Second law of motion apparatus	1	1	1	1	0	1	1	1	1	1	.89
Rotator	1	0	1	0	0	1	0	1	0	1	.44
Centrifugal ring	1	0	1	0	0	1	0	0	0	1	.33
Centrifugal hoop	1	1	1	0	0	1	1	1	0	1	.67
Centrifugal glass globe	1	0	1	0	0	1	0	0	0	1	.33
Siren & color disc	1	1	1	1	1	1	1	1	1	1	1.00
Gyroscope	1	0	1	1	0	1	1	0	0	1	.56
Set of constant level tubes	1	1	1	1	1	1	1	1	1	1	1.00
Set of Pascal's vase apparatus	1	0	1	1	0	1	1	0	1	1	.67
Cartesian diver	1	1	1	1	1	1	1	1	1	1	1.00

TABLE XI. (Continued)

Water motor	1	0	1	0	0	1	0	0	0	1	.33
Lift pump	1	1	1	1	0	1	1	1	1	1	.89
Force pump	1	1	1	0	1	1	1	1	1	1	.89
Aneroid barometer	1	0	1	0	0	1	1	0	0	0	.33
Maximum & minimum thermometer	1	0	1	0	0	1	1	0	0	1	.44
Hygrometer	1	0	1	1	0	1	0	0	0	1	.44
Air pump	1	1	1	1	1	1	1	1	1	1	1.00
Air pump plate	1	1	1	1	1	1	1	1	1	1	1.00
Vacuum gauge	1	0	1	0	0	1	0	0	0	0	.22
Bell jars	1	2	4	1	1	3	1	2	2	2	2.00
Spirometer	1	0	0	0	0	0	0	0	0	0	0.00
Guinea & feather tube	1	0	1	0	0	1	0	0	0	1	.33
Expansion ball & ring	1	1	2	1	1	1	1	1	2	1	1.22
Pulse glass	1	0	1	0	0	1	0	0	0	0	.22
Electromagnet	1	1	3	1	1	2	1	1	1	2	1.44
Static machine	1	1	1	1	1	1	1	1	1	1	1.00
Box form electroscope	1	1	1	0	0	1	0	0	0	1	.44
Electrolysis apparatus	1	0	1	0	0	1	1	0	0	1	.44
Universal support for electrolysis apparatus	1	0	1	0	0	1	0	0	0	0	.22
Induction coil	1	1	2	0	0	1	0	1	0	1	.67
Primary & secondary coil	1	0	1	1	0	1	1	1	0	1	.67
110-volt motor	1	0	1	1	0	1	0	0	0	1	.44

TABLE XI. (Continued)

Laboratory type transformer	1	0	1	0	0	1	0	0	0	0	.22
Telegraph set	1	0	1	1	0	1	0	0	1	1	.56
Lecture table galvanometer	1	0	1	1	0	1	1	0	1	1	.67
Volt-ammeter	1	1	4	1	1	2	1	1	2	2	1.67
Organ pipe	1	0	1	0	0	1	0	0	0	1	.33
Spiral spring 2 meters long	1	0	1	1	0	1	0	0	0	0	.33
Sonometer	1	1	2	1	0	1	1	0	0	1	.78
Optical disk	1	1	1	1	0	1	1	0	1	1	.78
Illuminator	1	1	1	1	0	1	1	0	0	1	.67
Jolly balance	1	1	1	1	0	1	1	0	1	1	.78
Universal truss units	3	0	0	0	0	0	0	0	0	0	0.00
Seconds pendulum	1	0	1	0	0	1	0	0	0	0	.22
Rotator accessories set	1	0	1	0	0	1	0	0	0	0	.22
Gas engine model	1	0	1	0	0	1	0	0	0	0	.22
Amperes frame	1	0	0	0	0	0	0	0	0	0	0.00
Oersted's law apparatus	1	0	0	0	0	1	0	0	0	0	.11
Vibrograph	1	0	1	0	0	0	0	0	0	0	.11
Manometric flame apparatus	1	0	1	0	0	0	0	0	0	0	.11
Spectroscope	1	0	1	0	0	1	0	0	0	0	.22

TABLE XII

Per Cent Of Recommended Demonstration Apparatus
In Physics Laboratories

Description	Per Cent in each Laboratory								
	A	B	C	D	E	F	G	H	I
Pairs of adhesion discs	100	200	100	100	100	100	100	200	100
Pairs of cohesion plates	0	100	0	0	100	100	0	0	100
Wire testing apparatus	0	100	0	0	100	0	0	0	0
Wheel & axle	0	100	100	0	100	0	100	0	100
Stop watch	100	300	100	100	100	100	100	100	100
Second law of motion apparatus	100	100	100	0	100	100	100	100	100
Rotator	0	100	0	0	100	0	100	0	100
Centrifugal ring	0	100	0	0	100	0	0	0	100
Centrifugal hoop	100	100	0	0	100	100	100	0	100
Centrifugal glass globe	0	100	0	0	100	0	0	0	100
Siren & color disc	100	100	100	100	100	100	100	100	100
Gyroscope	0	100	100	0	100	100	0	0	100
Set of constant level tubes	100	100	100	100	100	100	100	100	100
Set of Pascal's vase apparatus	0	100	100	0	100	100	0	100	100
Cartesian diver	100	100	100	100	100	100	100	100	100

TABLE XII. (Continued)

Water motor	0	100	0	0	100	0	0	0	100
Lift pump	100	100	100	0	100	100	100	100	100
Force pump	100	100	0	100	100	100	100	100	100
Aneroid barometer	0	100	0	0	100	100	0	0	0
Maximum & minimum thermometer	0	100	0	0	100	100	0	0	100
Hygrometer	0	100	100	0	100	0	0	0	100
Air pump	100	100	100	100	100	100	100	100	100
Air pump plate	100	100	100	100	100	100	100	100	100
Vacuum gauge	0	100	0	0	100	0	0	0	0
Bell jars	200	400	100	100	300	100	200	200	200
Spirometer	0	0	0	0	0	0	0	0	0
Guinea & feather tube	0	100	0	0	100	0	0	0	100
Expansion ball & ring	100	200	100	100	100	100	100	200	100
Pulse glass	0	100	0	0	100	0	0	0	0
Electromagnet	100	300	100	100	200	100	100	100	200
Static machine	100	100	100	100	100	100	100	100	100
Box form electroscope	100	100	0	0	100	0	0	0	100
Electrolysis apparatus	0	100	0	0	100	100	0	0	100
Universal support for electrolysis apparatus	0	100	0	0	100	0	0	0	0
Induction coil	100	200	0	0	100	0	100	0	100
Primary & secondary coil	0	100	100	0	100	100	100	0	100

TABLE XII. (Continued)

110-volt motor	0	100	100	0	100	0	0	0	100
Laboratory type transformer	0	100	0	0	100	0	0	0	0
Telegraph set	0	100	100	0	100	0	0	100	100
Lecture table galvanometer	0	100	100	0	100	100	0	100	100
Volt-ammeter	100	400	100	100	200	100	100	200	200
Organ pipe	0	100	0	0	100	0	0	0	100
Spiral spring 2 meters long	0	100	100	0	100	0	0	0	0
Sonometer	100	200	100	0	100	100	0	0	100
Optical disk	100	100	100	0	100	100	0	100	100
Illuminator	100	100	100	0	100	100	0	0	100
Jolly balance	100	100	100	0	100	100	0	100	100
Universal truss units	0	0	0	0	0	0	0	0	0
Seconds pendulum	0	100	0	0	100	0	0	0	0
Rotator accessories set	0	100	0	0	100	0	0	0	0
Gas engine model	0	100	0	0	100	0	0	0	0
Amperes frame	0	0	0	0	0	0	0	0	0
Oersted's law apparatus	0	0	0	0	100	0	0	0	0
Vibrograph	0	100	0	0	0	0	0	0	0
Manometric flame apparatus	0	100	0	0	0	0	0	0	0
Spectroscope	0	100	0	0	100	0	0	0	0
Average	41	118	48	23	98	50	38	43	75

C. The Laboratory Workshop

1. Home-made equipment. The wide-awake physics teacher is not content with a group of purchasing officials who are willing to buy everything suggested. The real physics teacher recognizes the value of home-made apparatus and equipment. Through this kind of material the teacher is able to develop inventive and mechanical skills, both of which are highly important skills to the scientist. A teacher who is hired to teach physics, but who has neither mechanical nor inventive skill, will never be a real physics teacher. By the same characteristics developed in pupils, one may know who the real physics students are. A store-made laboratory is not a proper laboratory. Projects in construction of various kinds of supplies needed should be given to all science students. The more common these projects are, the better. Too many laboratories with their highly specialized apparatus give the pupil the feeling that science is a very stilted thing and not the commonplace, everyday thing it is and it should be. Too much of every secondary science is of the aristocratic rather than of the common order. Nothing is more democratic than the subject matter of science.[18]

There is seldom a hint in the laboratory manuals to

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[18]State Department of Public Instruction, "Laboratory Construction, Equipment, and Exercises," Bulletin Number 65 H, (Indianapolis: Wm. B. Burford, 1926), p. 10.

the inexperienced teacher on simple and effective means of attaining experimental results. If there is an alternative between a complicated, expensive, manufactured piece of apparatus and a simple device which could be made in a manual training class or at home, the laboratory manuals almost invariably describe the complicated arrangement. Frequently the principles involved are actually obscured by the elaborateness of the set-up. Seldom is the apparatus stripped to the simplest form which causes the principles to stand out in bold relief.

This supposed dependence of the laboratory course on expensive apparatus has enabled the manufacturers of physical equipment to prey upon boards of education all over the country. The net result is that our physics laboratories are, on the whole, poorly equipped. This is the case even where considerable sums have been expended. The equipment of the physics laboratory in the high school need not be very expensive. One does not need a costly hypsometer and double-walled calorimeter set and metal clippings or shot to get reasonable accurate measurements of specific heat. Using short pieces of thick-walled metal pipe capped on one end, such as can be obtained at a plumber's shop, very good results can be obtained by pouring into the cup so formed a known amount of hot water at a known temperature. The only secret of success is the use of a large sample of the metal to be tested. One does not need expensive force boards, inclined planes, model electric motors, photometers, wheatstone's bridges, etc., to do good laboratory work. It is somewhat more convenient to use them if they are available, but in their absence no reasonably skilful teacher need allow the work to be seriously crippled. If encouraged the least bit many boys will be glad of an opportunity to assemble pieces of home-made apparatus either in the laboratory or in a corner of their basement or attic at home. And in such cases it has been my experience that the grasp of principles involved has equaled or exceeded that attained through the regular laboratory and classroom activities. Indeed the situation affords an opportunity for the use of the best features of the project method, and offers the further advantage that it in no way restricts the field of content materials presented through the regular school channels.[19]

To the end that creative ability is fostered by science courses, the teacher and the pupil should all be, or become, interested in the preparation of science materials. They need tools fitted to their specific science lines and a shop or even a small corner of the laboratory set apart for construction work. Neither teacher nor pupil should be satisfied with crude, rough work any more than they should be satisfied with crude, rough results gained from an experiment.[20]

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[19] Herbert Hazel, "High School Laboratory Work in Physics," School Science and Mathematics, (January, 1933), pp. 57-58.

[20] State Department of Public Instruction, op. cit., pp. 10-11.

If finances are limited, it is necessary in many cases to make a portion of one's own equipment. Ready-made equipment usually works better and requires less of the instructor's and student's time in assembling for the experiment. Since the equipment is not the thing we are interested in, but the results of the experiment, our interest is more or less confined to the equipment that is thoroughly usable.

From the writer's experience, better results are obtained if home-made equipment supplements rather than serves as a substitute for ready-made equipment.

2. Tools for the laboratory. Table XIII gives the amount of tools in the physics laboratories compared with the amount recommended by the State Department of Education. All of the laboratories had a pair of pliers but only 44 per cent of the laboratories had a set of cork borers. However, many of the schools have industrial arts rooms and have ample facilities on hand for making equipment. The average amount of tools for each laboratory ranged from 30 per cent to 100 per cent of the amount recommended.

Some of the laboratories had no home-made equipment whatever, while others had considerable home-made equipment. One physics instructor in particular had taken a special summer course in shop work. He had made approximately 150 dollars worth of apparatus that was as good, if not better, than could be obtained from the apparatus companies. He had turned out a set of weights that were accurate to one-thousandth of a gram. Besides making the new equipment he had repaired many pieces

TABLE XIII

Tools In The Laboratory Workshop

Description	Quantity Recommended	Quantity on Hand									
		A	B	C	D	E	F	G	H	I	Average for Articles
Vise, anvil type	1	1	1	1	0	1	1	1	0	1	.78
Drill, hand type	1	1	1	0	0	1	0	1	1	1	.67
Hack saw	1	0	1	1	1	1	1	1	1	1	.89
Pair of 5½ in. pliers	1	1	1	1	1	1	1	1	1	1	1.00
6 in. screw driver	1	1	1	1	1	1	0	1	1	1	.89
8 in. screw driver	1	1	1	1	0	1	1	1	0	1	.78
Pair of tinner's snips	1	0	1	1	0	1	1	0	0	1	.56
Soldering outfit	1	1	1	0	0	1	1	1	1	1	.78
Monkey wrench	1	1	1	1	0	1	0	1	0	0	.56
Cork borers (set of 3)	1	1	0	0	0	1	1	0	0	1	.44
Average for schools		.80	.90	.70	.30	1.00	.70	.80	.50	.90	

of apparatus, rewound old motors and had built up a very fine laboratory of equipment. He had accomplished all this in spite of the fact that he was principal and had many other duties to perform.

Not all instructors have the time available, nor are willing to take the time, to make equipment. Many of the physics instructors are also principals and have little available time at their disposal. In such cases the apparatus companies can be relied upon to furnish the laboratory with very fine equipment.

Some of the home-made equipment found in the physics laboratories included resistance boards, lamp-board rheostats, communicating vessels, electrophorus apparatus, weights, overflow cans, specific gravity specimens, electric arcs, electric motors, collision apparatus (Newton's second law), center of gravity apparatus, conduction apparatus, electrolysis apparatus, and model water pumps.

3. General stock for the laboratory. The amount on hand of the general stock recommended for the physics laboratory is given in Table XIV.

Table XV gives the per cent of the recommended general stock in the physics laboratories. The average for the different schools ranged from 40 per cent for the lowest to 133 per cent for the highest.

TABLE XIV

General Stock In The Physics Laboratories

Description	Quantity Recommended	Quantity on Hand									
		A	B	C	D	E	F	G	H	I	Average
Lbs. of lead shot	4	2	4	3	1	4	2	4	3	3	2.9
Paraffin candles	12	6	18	8	5	10	9	7	6	11	8.9
Mohr's clamp	4	3	4	4	1	4	3	4	3	5	3.4
Doz. of assorted corks	12	3	12	4	2	10	$4\frac{1}{2}$	5	$3\frac{1}{2}$	3	5.2
Evaporating dishes	3	3	3	3	1	3	2	2	3	3	2.6
Flat bottom flasks	12	4	12	5	3	10	6	5	4	8	6.3
Round bottom flasks (16 oz.)	2	2	2	2	1	2	2	2	2	2	1.9
Round bottom flasks (32 oz.)	2	1	2	2	2	1	1	2	1	2	1.6
Glass funnels	2	1	2	1	0	2	1	1	0	1	1.0
Lbs. 5 mm glass tubing	1	$\frac{1}{2}$	1	$\frac{3}{4}$	$\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	1	.7
Lbs. 6 mm glass tubing	1	1	1	1	$\frac{1}{2}$	$\frac{3}{4}$	1	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{1}{2}$	.8
Lbs. capillary glass tubing	1	$\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{1}{4}$	1	$\frac{1}{2}$	1	$\frac{1}{4}$	$\frac{3}{4}$	.6
Volumetric pipettes	2	1	2	0	0	1	1	1	0	1	.8
Lbs. of 1 hole rubber stoppers	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$	.4
Lbs. of 2 hole rubber stoppers	1	$\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	.6

TABLE XIV. (Continued)

Ft. of ¼ in. rubber tubing	6	5	6	4	3	6	6	6	5	6	5.2
Ft. of 1/16 in. rubber tubing	6	7	6	6	5	8	10	5	4	8	6.6
6 in. x ¾ in. test tubes	24	12	24	10	5	18	10	12	8	9	12.0
8 in. x 1 in. test tubes	12	5	12	6	0	12	10	8	2	12	7.5
Lbs. of No. 20 annunciator wire	1	2	6	4	1	2	1	1½	3	2	2.5
Lbs. of No. 18 copper wire	1	½	2	1	1	3	2	2	1½	2	1.7
Oz. of No. 24 copper wire	4	3	8	3	0	6	2	3	2	4	3.4
Oz. of No. 30 copper wire	4	3	10	5	2	4	4	2	4	3	4.1
Oz. of No. 24 German silver wire	4	4	8	3	4	5	3	4	0	6	4.1
Oz. of No. 30 German silver wire	4	3	4	2	0	2	4	4	4	3	2.9
Oz. of No. 36 German silver wire	4	4	8	3	5	7	6	3	4	4	4.9
Pkgs. of co-ordinate paper	4	1	3	2	0	1	2	1	½	2	1.4
Lbs. of nitric acid	1	1	1	1	½	¾	1	1	1	2	1.0
Lbs. of sulphuric acid	1	1	1	2	¾	1	1	2	2	1	1.3
Lbs. of aluminum metal pellets	1	½	1	¾	0	½	1	1	0	¾	.6

TABLE XIV. (Continued)

Lbs. of copper metal shot	1	0	1	½	0	1	½	0	0	1	.4
Lbs. of mercury	2	1	2	2	1	2	1	1½	2	2	1.6
Lbs. of paraffin	2	1	2	½	¼	1½	1	2	½	1	1.1

TABLE XV

Per Cent Of General Stock In The Physics Laboratories

Description	Per Cent of General Stock on Hand								
	A	B	C	D	E	F	G	H	I
Lbs. of lead shot	50	100	75	25	100	50	75	100	75
Paraffin candles	50	150	75	42	83	75	58	50	92
Mohr's clamp	75	100	100	25	100	75	100	75	125
Doz. of assorted corks	25	100	33	13	83	38	42	29	25
Evaporating dishes	100	100	100	33	100	67	67	100	100
Flat bottom flasks	33	100	42	25	83	50	42	33	67
Round bottom flasks (16 oz.)	100	100	100	50	100	100	100	100	100
Round bottom flasks (32 oz.)	50	100	100	100	50	50	100	50	100
Glass funnels	50	100	50	0	100	50	50	0	50
Lbs. 5 mm glass tubing	50	100	75	25	100	75	50	50	100

TABLE XV. (Continued)

Lbs. 6 mm glass tubing	100	100	100	50	75	100	75	75	50
Lbs. capillary glass tubing	50	100	50	25	100	50	100	25	75
Volumetric pipettes	50	100	0	0	50	50	50	0	50
Lbs. of 1 hole rubber stoppers	50	100	125	50	100	50	100	50	100
Lbs. of 2 hole rubber stoppers	50	100	50	25	75	50	25	50	75
Ft. of $\frac{1}{4}$ in. rubber tubing	83	100	67	50	100	100	100	83	100
Ft. of 1/16 in. rubber tubing	117	100	100	83	133	167	83	67	133
6 in. x $\frac{3}{4}$ in. test tubes	50	100	42	41	75	42	50	33	38
8 in. x 1 in. test tubes	42	100	50	0	100	83	67	17	100
Lbs. of No. 20 annunciator wire	200	600	400	100	200	100	150	300	200
Lbs. of No. 18 copper wire	50	200	100	100	300	200	200	150	200
Oz. of No. 24 copper wire	75	200	75	0	150	50	75	50	100
Oz. of No. 30 copper wire	75	250	125	50	100	100	50	100	75
Oz. of No. 24 German silver wire	100	200	75	100	125	75	100	0	150
Oz. of No. 30 German silver wire	75	100	50	0	50	100	100	100	75

TABLE XV. (Continued)

Oz. of No. 36 German silver wire	100	200	75	125	175	150	75	100	100
Pkgs. of co-ordinate paper	25	75	50	0	25	50	25	13	50
Lbs. of nitric acid	100	100	100	50	75	100	100	100	200
Lbs. of sulphuric acid	100	100	200	75	100	100	200	200	100
Lbs. of aluminum metal pellets	50	100	75	0	50	100	100	0	75
Lbs. of copper metal shot	0	100	50	0	100	50	0	0	100
Lbs. of mercury	50	100	100	50	100	50	75	100	100
Lbs. of paraffin	50	100	25	13	75	50	100	25	50
Average	67	133	89	40	104	85	80	67	95

VIII. LOSS IN PHYSICS EQUIPMENT.

"Costly thy habit as thy purse can buy" may at times express the thought of a taxpayer as he inspects modern laboratories and their equipment in some of the secondary schools. In marked contrast to this, however, the equipment and supplies of the smaller high schools oftentimes will be found wretchedly inadequate for the teaching undertaken. Oftentimes this pinch of poverty in the science courses like that are not infrequently directly traceable to waste resulting from ignorance in making purchases, and from shiftlessness in care of what has been purchased. Liberal treatment by superintendents and school boards may be won or lost to science teachers and their successors through competency or incompetency in use and storage of science apparatus and supplies.

Both school architecture and school furniture are now so fully standardized that in cities and larger towns science teachers are largely spared responsibility for the arrangement and equipment of laboratories. But there are yet many schools in which science is taught under the heavy handicap of ill-advised furnishings, and where available funds for betterments are so limited that small outlays to improve the teaching service assume an undue importance. It is chiefly with the needs and the teaching conditions in these smaller high schools that we are here concerned. In the smaller high schools where one teacher has, it may be, all the science subjects, the teaching problems are entirely different from those of special teachers in large high schools. Nevertheless, economy rather than waste applies equally well to all science teachers, and is as applicable to their time and energy as it is to expenditures for apparatus and supplies.[21]

Tables XVI to XXIV show the amount of physics equipment bought during the period of study, and how much of this has been used, lost, broken, stolen, or is still in use.

Table XVI is for school A. The period studied is six years. The total cost of the equipment purchased during the six years was $152.80. Of this, $36.74 worth was used, broken, lost, or stolen, and $116.06, or 75 per cent of the total, was still in use. The average loss was $6.12 a year.

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[21]H. Brownell and F. B. Wade, The Teaching of Science and The Science Teacher, (New York: The Century Co., 1925), pp. 35-36.

TABLE XVI

Loss In Physics Equipment In School A

Description	Price	Still in Use	Used or Broken	Lost or Stolen
1 Boyle's law apparatus	$ 10.75	1		
2 thermometers	2.00		2	
1 linear expansion apparatus	1.10			1
1 concave mirror	.75	1		
1 lb. annunciator wire, #20	.90			1
1 induction coil	12.00	1		
1 sonometer	16.00		1	
1 A. C. ammeter	31.00	1		
1 A. C. voltmeter	33.50	1		
6 dry cells	2.70			6
1 clamp	.15	1		
1 lb. mercury	2.50		1	
1 bulb for battery charger	3.39		1	
1 baby gasoline torch	1.15	1		
1 tripod support	.63	1		
1 double scale thermometer	1.25		1	
1 wood calorimeter	.30	1		
1 dew-point apparatus	.90	1		
1 double graduated cylinder	.60		1	
1 thermometer	1.75		1	
1 pulley	.60	1		

TABLE XVI. (Continued)

1 Hall's carriage	$ 1.00	1		
1 copper boiler	3.85	1		
1 cardboard tube	.30	1		
1 calorimeter	2.75	1		
1 lb. lead shot	.30	1		
1 lb. copper shot	.40	1		
1 lb. steel shot	.20	1		
1 pkg. blue print paper	.20		1	
1 compass, 40 mm	1.10		1	
1 trip balance	10.00	1		
1 hydrometer	.70	1		
1 Mohr's pipette	.48	1		
1 set cork borer	.40	1		
3 lbs. glass tubing	1.50	2	1	
1 thermometer	1.20			1
3 dry cells	1.35	3		
1 lb. copper	1.15	1		
10 ft. rubber tubing	.30			10
1 lb. iron filings	.20	1		
1 blow pipe	.15	1		
1 alcohol thermometer	.35	1		
4 oz. German silver wire, #20	.90	2	2	
Total	$152.80	$116.06	$30.54	$6.20

Table XVII shows the loss in physics equipment in school B. The period is for three years. During the three years, $111.97 worth of equipment was purchased. Of this amount, $9.90 worth was used, broken, lost, or stolen. This was an average loss of $3.30 a year. At the end of the three-year period, $102.07 or 91.2 per cent of the equipment was still in use.

TABLE XVII

Loss In Physics Equipment In School B

Description	Price	Still in Use	Used or Broken	Lost or Stolen
2 sq. ft. copper gauze	$ 1.20	1	1	
2 lbs. mercury	4.60	1	1	
36 squares wire gauze	1.20	36		
1 spool piano wire, #25	.10	1		
5 specific gravity bottles	1.60	5		
6 meter sticks	1.68	6		
1 model lift pump	.80	1		
1 model force pump	.80	1		
1 model hydraulic press	1.16	1		
24 binding posts	1.68	24		
12 compasses	1.50	6	6	
1 air thermometer	.12	1		
6 lever holders for meter stick	.84	6		

TABLE XVII. (Continued)

6 knife edge clamps	$ 2.88	6		
6 wooden balls	.24	6		
1 resistance board	2.50	1		
1 extension cord, 12 ft. with connections	1.10			1
1 hack saw	1.30	1		
6 brass protractors	.72	4		2
12 English metric rulers	.36	12		
1 rubber dam	.15	1		
7 spring balances	2.45	7		
1 spool silk thread	.10	1		
1 fish line	.16	1		
1 ball heavy chalk line	.05	1		
1 D. C. ammeter	17.40	1		
1 A. C. ammeter	8.75	1		
1 spring balance	.45	1		
18 binding posts	.59	18		
3 catch buckets for overflow can	.90	3		
48 candles	1.12	36	12	
6 right angle clamps	1.20	6		
3 condenser clamps	1.05	3		
6 glass funnels	1.32	6		
1 pocket knife	1.00	1		
5 lamp sockets on meter stick support	7.00	5		

TABLE XVII. (Continued)

5 candle holders on meter stick support	$ 1.25	5		
4 cylindrical graduates	1.80	3	1	
3 spring & weight holders	.39	3		
1 laboratory stop watch	6.90	1		
24 pith balls	.36	12	12	
1 tissue tassel	.06		1	
1 pr. pith images	.20		1	
1 insulated sphere	2.40	1		
12 linen testers	2.64	10		2
1 glass whistle	1.20	1		
12 slotted iron weights	1.80	12		
2 triple pulleys	.60	2		
7 double pulleys	1.54	7		
7 single pulleys	1.12	7		
1 quart tin measure	.15	1		
1 adjustable tuning fork	1.10	1		
5 sheets thin copper foil	.60	4	1	
2 lbs. mercury	3.40		2	
2 sq. ft. copper gauze	.80	2		
2 lbs. mercury	2.50	2		
6 electrolysis apparatus	7.50	6		
6 ring stands	2.70	6		
1 vernier caliper	.65	1		
1 micrometer	2.10	1		

TABLE XVII. (Continued)

6 brass protractors	$ .60	6		
1 universal hydrometer	.50	1		
2 barometer tubes	.70	2		
2 hydrometer jars	.72	2		
6 D clamps	2.52	6		
7 knife edge clamps	2.80	6	1	
12 knitting needles	.10	12		
1 set platinum electrodes	.70	1		
Total	$111.97	$102.07	$8.56	$1.34

Table XVIII covers a three-year period for school C. The total cost of the physics equipment during the three years was $91.72. Of this amount, $17.24 worth of equipment was used, broken, lost, or stolen. $74.48 worth or 81.2 per cent of the equipment was still in use. The average loss per year was $5.75.

TABLE XVIII

Loss In Physics Equipment In School C

Description	Price	Still in Use	Used or Broken	Lost or Stolen
10 beakers, 250 cc	$ 1.90	10		
15 flasks, 250 cc	2.25	15		
3 flasks, 500 cc	.66	3		
1 bell jar	3.60	1		
20 wire gauzes	1.40	20		
5 glass funnels	1.90	5		
1 glass funnel	.60	1		
5 lbs. glass tubing	1.90	5		
1 lb. glass tubing	.60	1		
5 lbs. glass tubing	3.67	5		
5 lbs. mercury	8.00		5	
1 bakelite pan for balance	1.00	1		
8 copper elements	1.12	8		
12 zinc elements	.60	12		
1 hydrometer	1.35	1		
4 oz. German silver wire, #30	1.35	4		
3 lenses	2.75	3		
4 bar magnets	1.40	4		
1 set cylinders	.75	1		
6 dry cells	1.80		6	
1 storage battery	5.75	1		

TABLE XVIII. (Continued)

4 electric bells	$ 2.40	3		1
3 magnetic compasses	1.50	2	1	
3 thermometers	3.00		3	
1 air thermometer	.20	1		
12 candles	.60	6	6	
24 knitting needles	.36	18	6	
6 dry cells	2.10	6		
2 spring & weight holders	.50	2		
2 spring balances	1.70	2		
2 hydrometer jars	1.35	2		
2 thermometers	2.40	2		
2 bar magnets	.70	2		
2 battery jars	1.70	2		
1 spool piano wire, #18	.75	1		
1 book silver foil	.45	1		
1 pkg. darning needles	.15	1		
1 pkg. knitting needles	.40	1		
1 box sealing wax	.80	1		
1 mica sheet	.20	1		
1 asbestos sheet	.50	1		
1 force pump	1.50		1	
2 sq. ft. rubber dam	.50	2		
1 loadstone	.25			1
1 silk pad	.50	1		

TABLE XVIII. (Continued)

12 binding posts	$ .90	12		
1 switch	.40	1		
1 glass cutter	.20	1		
1 soldering copper	.50	1		
1 set weights	1.45	1		
4 brushes	.55	4		
2 graduates, 50 cc	1.40	2		
2 graduates, 250 cc	2.50	2		
1 pipette	.36	1		
48 test tubes	1.00	48		
5 lbs. mercury	10.00	5		
3 thermometers	3.60	2	1	
Total	$ 91.72	$74.48	$16.39	$ .85

The loss in physics equipment in school D during a three-year period is shown in Table XIX. The total amount of physics equipment bought was $17.46. Of this amount, $4.05 worth of equipment was used or broken, leaving a total of $13.41, or 76.7 per cent of the equipment still in use. The average loss per year was $1.35.

TABLE XIX

Loss In Physics Equipment In School D

Description	Price	Still in Use	Used or Broken	Lost or Stolen
1 electrolysis apparatus	$ 4.20	1		
10 ft. rubber tubing	.25		10	
1 tuning fork	1.25	1		
4 dry cells	1.60		4	
2 dry cells	.70	2		
1 tuning fork	1.25	1		
Lumber for physics	.55			
3 thermometers	3.00	2	1	
1 electric bell	.60	1		
2 magnetic compasses	.30	2		
2 single pulleys	.70	2		
3 hydrometer jars	1.95	2	1	
1 electric bell	.75	1		
3 evaporating dishes	.36	3		
Total	$ 17.46	$ 13.41	$ 4.05	

Table XX shows the loss in physics equipment in school E. The period is for three years. At the end of the three-year period, 98.2 per cent of the equipment purchased was still in use. The loss averaged only $2.27 a year.

TABLE XX

Loss In Physics Equipment In School E

Description	Price	Still in Use	Used or Broken	Lost or Stolen
1 micrometer caliper	$ 5.50	1		
1 vernier caliper	1.75	1		
1 measuring disc	.20	1		
3 meter sticks	1.05	3		
1 iron ball, 1 in.	.50	1		
2 cork balls, 1 in.	.25	2		
2 hardwood balls, 1 in.	.16	2		
1 force board	4.50	1		
2 double pulleys	.90	2		
1 Hall's carriage	1.00	1		
2 pendulum clamps	2.50	2		
2 glass tubes	4.00	2		
3 manometer tubes	1.05	3		
2 hydrometer tubes	1.00	2		
2 hydrometer tubes	.90	2		
2 battery jars	1.70	2		
1 steam generator	4.50	1		
1 Charles' law tube	1.25	1		
1 iron rod	.15	1		
2 magnet boards	1.70	2		
2 magnets	.80	2		
3 electric bells	.60	2		

TABLE XX. (Continued)

2 compasses, 50 mm	$ 1.20	2		
2 compasses	.30	2		
1 battery	1.00	1		
2 linen testers	1.00	2		
1 metric chart	2.00	1		
1 capillary tube apparatus	.60	1		
1 rotator accessories set	9.00	1		
1 barometer	27.50	1		
1 air thermometer	.20	1		
1 gas engine	14.50	1		
1 lodestone	.25	1		
1 electromagnet	2.50	1		
1 friction rod	.50	1		
2 silk pads	1.00	2		
2 flannel pads	.80	2		
2 cat skins	2.00	2		
1 pkg. pith balls	.50		1	
1 electroscope	.90	1		
1 ring chain & cylinder	.80	1		
1 electrostatic demonstration outfit	35.00	1		
1 electrolysis apparatus	5.00	1		
1 induction coil	7.50	1		
1 primary & secondary coil	4.00	1		
1 telegraph key	2.75	1		

TABLE XX. (Continued)

1 telegraph sounder	$ 3.00	1		
1 telephone receiver	2.25	1		
1 telephone transmitter	2.50	1		
1 motor	4.25	1		
1 Wheatstone bridge	6.00	1		
1 resistance coil	5.00	1		
1 single-contact key	1.00	1		
1 knife switch	.50	1		
1 volt-ammeter	18.00	1		
1 tuning fork	1.65	1		
1 tuning fork	1.65	1		
2 lenses	.80	2		
1 lens	.35	1		
1 lens	.50	1		
1 prism	.50	1		
12 candles	.25	6	6	
1 candle	.20		1	
1 set of weights	3.00	1		
1 clamp	.35	1		
1 tube & scale	.40	1		
1 clamp	.25	1		
1 flask, 250 cc	.24	1		
1 gauze, 4 x 4 in.	.05	1		
1 graduate, 100 cc	1.35	1		
12 ft. tubing, ¼ in.	1.68	9	3	

TABLE XX. (Continued)

1 triple beam trip balance	$ 9.00	1		
1 set of weights	.75	1		
3 thermometers	1.25	2	1	
1 spool piano wire, #28	.15	1		
1 spool piano wire, # 30	.20	1		
1 adhesion disc	.30	1		
1 hand driven duo-cycle pump	65.00	1		
1 organ pipe	7.50	1		
1 mirror	.75	1		
1 dew-point apparatus	1.00	1		
1 convection apparatus	2.25	1		
1 extra chemicals	1.00	1		
1 hygrometer	7.25	1		
1 pith balls	.50	1		
1 set sympathetic forks	17.50	1		
1 violin bow	1.75	1		
1 refraction tank	1.50	1		
1 Kundt's apparatus	7.50	1		
4 oz. cork dust	.20	2	2	
1 camera obscura	2.25	1		
4 thermometers	4.80	3	1	
1 lb. mercury metal	3.50	½	½	
1 resistance box	11.50	1		
2 clamps	1.50	2		

TABLE XX. (Continued)

1 beaker, 600 cc	$ .35	1		
1 beaker, 800 cc	.40	1		
1 beaker, 1000 cc	.54	1		
1 blast lamp	8.50	1		
3 heat tubes	.30	3		
1 set of weights	3.00	1		
1 pkg. of corks	.65	1		
1 lb. stoppers, 1 hole, #0.3	1.75	1		
1 lb. stoppers, 2 hole, #0.3	1.75	1		
10 stoppers, 2 hole, #0.7	1.50	8	2	
1 lb. annunciator wire, #18	.70	½	½	
1 spool copper wire, #20	.30	1		
1 spool brass wire, #20	.30	1		
1 spool copper wire, #28	.45	1		
4 oz. copper wire, #26	.35	4		
1 lb. copper wire, #18	1.25	1		
4 oz. German silver wire, #28	1.10	4		
4 oz. German silver wire, #24	1.10	4		
4 oz. German silver wire, #30	1.70	4		
4 oz. fuze wire, ½ ampere	1.70	2	2	
1 spool piano wire, #26	.15	1		
1 spool piano wire, #24	.15	1		
Total	$384.47	$377.65	$6.22	$ .60

Table XXI, for school F, gives the amount of physics equipment bought in the past three years and the loss resulting from the equipment being used, broken, lost, or stolen. The equipment purchases totaled $84.69. Of this amount $73.55 or 86.8 per cent of the total was still in use. The loss averaged $3.71 a year for the three-year period.

TABLE XXI

Loss In Physics Equipment In School F

Description	Price	Still in Use	Used or Broken	Lost or Stolen
6 meter sticks	$ 2.10	6		
1 vernier caliper	1.75	1		
1 brass cylinder	.50	1		
3 battery jars	4.50	2	1	
4 lever holders	1.00	4		
2 spring balances, 200 g.	1.50	2		
3 spring balances, 250 g.	3.75	3		
1 spring balance, 500 g.	2.00	1		
2 ring stands	2.80	2		
1 Boyle's law tube	.85	1		
2 burette clamps	.70	2		
1 spring & weight holder	.25	1		
3 thermometers C.	3.00	1	2	
1 thermometer F.	1.00	1		
1 dew-point apparatus	1.00	1		

TABLE XXI. (Continued)

2 glass friction rods	$ .60	2		
2 ebonite friction rods	.70	2		
1 resistance coil, 500 ohm	.50	1		
1 resistance coil, 10 ohm	.35	1		
1 resistance coil, 100 ohm	.50	1		
2 magnetic compasses, 50 mm	1.10	1	1	
2 magnetic compasses, 25 mm	.50	1		1
1 silk friction pad	.50	1		
1 flannel friction pad	.35	1		
1 lb. assorted capillary tubing	1.10	1		
5 lbs. assorted glass tubing	3.00	2	3	
1 barometer tube	.50	1		
1 soldering outfit	1.50	1		
24 test tubes	.64	10	14	
3 tubing clamps	.46	3		
1 pr. condenser plates	.50	1		
1 hydrometer jar	.65	1		
1 resonance tube	1.25	1		
4 tuning forks	5.00	4		
1 prism	.50	1		
1 reading glass	.75			1
1 lens, 10 cm focus	.30	1		
1 lens, 20 cm focus	.30	1		
1 lens, 30 cm focus	.30	1		

TABLE XXI. (Continued)

2 push buttons	$ .30	2		
1 electric bell	.35	1		
1 lens support	.12	1		
1 screen support	.10	1		
6 ft. rubber tubing, $\frac{1}{4}$ in.	.50	3	3	
6 ft. rubber tubing, 3/16 in.	.50	4	2	
2 lbs. lead shot	.40	2		
1 lb. annunciator wire, #20	.90	$\frac{1}{2}$	$\frac{1}{2}$	
1 lb. annunciator wire, #24	1.25	$\frac{1}{2}$	$\frac{1}{2}$	
1 lb. annunciator wire, #18	.75	1		
4 oz. iron wire, #30	.15	3	1	
4 oz. copper wire, #30	.85	3	1	
1 oz. German silver wire, #24	.30	1		
1 oz. German silver wire, #30	.40	1		
2 thistle tubes	.36	2		
2 linen testers	1.00	1		1
12 paraffin candles	.40	6	6	
1 pkg. coordinate paper	.22	$\frac{1}{2}$	$\frac{1}{2}$	
1 roll piano wire, #00	.25	$\frac{1}{2}$	$\frac{1}{2}$	
1 flat bottom flask, 1000 cc	.35	1		
2 flat bottom flasks, 500 cc	.50	1	1	
2 flat bottom flasks, 250 cc	.40	2		
1 funnel, 100 mm	.36	1		
2 funnels, 75 mm	.56	1	1	

TABLE XXI. (Continued)

3 evaporating dishes, #1	$ .81	3		
1 lb. asstd. rubber stoppers	1.50	1		
1 pr. platinum electrodes	1.75	1		
1 gyroscope	.75	1		
1 siren & color disc	2.00	1		
1 book aluminum leaves	.50	$\frac{3}{4}$	$\frac{1}{4}$	
12 watch springs	.25	8	4	
6 reagent bottles, 4 oz.	2.40	6		
2 test tube brushes	.20	2		
4 wire gauze, 5 x 5 in.	.60	4		
1 beaker, 600 cc	.30	1		
1 beaker, 250 cc	.21	1		
1 triangular file, 6 in.	.10	1		
1 pkg. picture wire	.10	1		
1 galvanometer	6.75	1		
1 pneumatic trought	.80	1		
6 watch glasses, 3 in.	.30	4	2	
2 rubber dams	.50	2		
1 air pump	5.00	1		
1 pkg. blue print paper	.50		1	
Total	$84.69	$73.55	$9.64	$1.50

The loss in physics equipment for school G is shown in Table XXII. Since this school has not offered physics for several years prior to 1933-34, the data in this table could be obtained for only one year. The total amount purchased was $27.10. Of this amount $25.68 or 91.5 per cent of the equipment was still in use. The loss for the year amounted to $1.42.

Besides the equipment shown in the table, the instructor made about $150 worth of equipment at small cost.

TABLE XXII

Loss In Physics Equipment In School G

Description	Price	Still in Use	Used or Broken	Lost or Stolen
500 g. mercury	$ 1.70	200 g.	300 g.	
3 tubing clamps	.30	3		
1 condenser tube	.70	1		
1 universal clamp & holder	.40		1	
1 electrolysis apparatus	5.00	1		
1 electrophorus apparatus	1.00	1		
4 electric receptacles	.40	4		
2 pyrex beakers, 500 cc	.50	2		
2 R. B. flasks, 500 cc	.80	2		
2 R. B. flasks, 500 cc	.60	2		
3 thistle tubes	.40	3		
4 test tube holders	.30	4		
1 laboratory table	15.00	1		
Total	$27.10	$26.70	$ .40	

The loss in physics equipment in school H is shown in Table XXIII. The period is for four years. The total amount of physics equipment purchased amounted to $165.24. Of this amount, $125.61 worth was still on hand at the end of the four-year period. This was 76 per cent of the total amount purchased. The loss due to equipment used, broken, lost, and stolen amounted to $39.63 or an average of $9.91 per year.

TABLE XXIII

Loss In Physics Equipment In School H

Description	Price	Still in Use	Used or Broken	Lost or Stolen
5 weights, 1 gram	$ .40	5		
1 demonstration battery	1.25	1		
2 storage batteries	12.00	1	1	
1 battery tester	.75	1		
4 electric bells	2.40	4		
2 electric buzzers	1.00	2		
10 electric keys	2.75	9		1
1 electric key	.75	1		
3 electric receptacles	1.20	2		1
3 magnetic compasses	1.50	1	2	
4 carbon filament lamps	1.30	4		
1 volt-ammeter	20.00	1		
1 electric motor	2.00	1		

TABLE XXIII. (Continued)

18 electric motors	$ 2.00		18	
3 electric resistance coils	.75	3		
1 set electric chimes	2.00	1		
1 electric plume	.65	1		
6 Geissler tubes	4.25	6		
1 pr. image plates	2.50	1		
1 pr. pith images	.75	1		
1 lightning plate	1.50	1		
1 steam generator	4.50	1		
1 air thermometer	.20	1		
1 compound bar	.60	1		
1 radiometer	2.50	1		
5 lbs. lead shot	1.00	4		1
6 meter sticks	1.87	6		
9 thermometers	9.00	3	6	
2 beakers, 500 cc	.40	2		
2 lbs. mercury	4.00	1	1	
1 Newton's color disc	1.00	1		
3 linen testers	1.50	3		
2 candle holders	.47	2		
1 Bunsen screen	.25	1		
12 candles	.60	2	10	
2 illuminator bulbs	1.50		2	
2 boxes blank cartridges	1.00	1	1	

TABLE XXIII. (Continued)

1 dipping needle	$ 3.00	1		
1 magnetic needle	.75	1		
1 loadstone	.25	1		
3 doz. needles	.75	1	2	
1 vernier caliper	1.75			1
3 pencil compasses	.45	3		
12 Prince Rupert drops	.60	4	8	
1 rubber dam	.25		1	
1 set communicating vessels	1.00	1		
3 glass hydrometers	2.25	2	1	
1 hydrometer tube	.40		1	
2 hydrometer jars	2.10	2		
1 battery jar	3.60		1	
1 model hydraulic press	2.00	1		
4 suspension balls	.75	4		
1 conical spring	.50	1		
1 dew-point apparatus	1.00	1		
1 adhesion disk	.30	1		
1 soldering outfit	.90	1		
1 pr. wire pliers	.75	1		
3 mounted tuning forks	15.00	3		
2 tuning forks	2.50	2		
1 horse & rider	1.10	1		
1 sheet zinc	.50	½	½	
12 dry cells	4.80		12	

TABLE XXIII. (Continued)

6 dry cells	$ 2.40	6		
2 screw drivers	.30	2		
2 thermometers	3.00	2		
1 transformer, 6-volt	1.00		1	
3 spring balances	2.25	3		
6 meter sticks	2.10	6		
2 glass cylinders	2.00	2		
2 lbs. bell wire	.50	1	1	
12 electric fuzes	.50		12	
3 graduated cylinders	1.80	1	2	
4 thermometers	4.00	2	2	
6 floating magnets	.40	6		
3 asbestos pads	.45	3		
1 asbestos sheet	.60	1		
1 glass cutter	.10	1		
1 pkg. blue print paper	.40		1	
1 resistance board	2.00	1		
2 Fahrenheit thermometers	2.00	1	1	
Total	$165.24	$125.61	$36.80	$2.83

Table XXIV is for school I. The loss in physics equipment is shown for a five-year period. The total amount of equipment purchased was $166.69. Of this amount $149.02 or 90.1 per cent was still in use at the end of the period.

The total loss was $17.67, or $3.53 a year.

TABLE XXIV

Loss In Physics Equipment In School I

Description	Price	Still in Use	Used or Broken	Lost or Stolen
2 lbs. mercury	$ 6.40			2
1 pkg. darning needles	.15	1		
1 set specific gravity specimens	.75	1		
2 compasses, 40 mm	2.50	2		
2 thermometers	2.50		2	
12 zinc elements	.60		12	
6 copper elements	.36	6		
1 pr. carbon electrodes	1.00	1		
1 D'Arsonval galvanometer	6.25	1		
1 spiral spring	2.00	1		
1 Mason's chalk line	.12	1		
2 sq. ft. rubber dam	.50		2	
1 manometer tube	2.00	1		
1 friction rod	.40	1		
1 flannel cap	.25	1		
2 beakers, 2000 cc	1.96		2	
24 ft. rubber tubing	4.32	18	6	
1 balance	15.00	1		
1 set of weights	5.25	1		

TABLE XXIV. (Continued)

1 spring & weight holder	$ .25	1		
1 spring	.15	1		
1 set cork borers	.50	1		
1 electric whirl	1.35	1		
2 magnets, cobalt-chromium	1.35	2		
1 pkg. steel balls	.25	1		
1 magnetic compass	1.25	1		
1 bakelite pulley	.45	1		
5 thermometers	5.00	4	1	
6 copper elements	.30	6		
6 lead elements	.36	6		
12 zinc elements	.60	12		
1 water hammer	1.20	1		
1 hydrometer jar	1.00	1		
1 galvanoscope	1.75	1		
2 lbs. mercury	5.80	2		
4 oz. acetamide	1.00	4		
1 lb. ether	.60		1	
2 beakers, 2000 cc, pyrex	1.96	2		
2 lbs. glass tubing, 7 mm	1.30	2		
1 battery tester	.75			1
1 lantern slide box	1.20	1		
1 compass	1.25	1		
1 sq. ft. rubber dam	.25	1		

TABLE XXIV. (Continued)

6 zinc elements	$ .30	6		
2 lbs. mercury	6.40	2		
2 lbs. lead shot	.80	2		
1 reading glass	.60	1		
6 meter sticks	1.80	6		
2 slotted weights, 10 gm.	.32	2		
2 slotted weights, 20 gm.	.36	2		
1 glass tube, 4 cm	.75	1		
6 steel balls, ¾ in.	.48	6		
2 thermometers	2.00	1	1	
2 bar magnets	.80	2		
2 glass static rods	.60	2		
2 compasses	1.50	2		
6 zinc elements	.60	4	2	
2 wood blocks	.20	2		
1 electric bell	.65	1		
1 cryophorus	1.50	1		
1 set color discs	1.50	1		
1 diffraction grating replica	1.75	1		
1 set lenses	2.00	1		
1 vernier caliper	1.75	1		
1 set density specimens	2.25	1		
1 pulley	.90	1		
1 pulley chord	.25	1		

TABLE XXIV. (Continued)

1 battery tester	$ .75	1		
2 weights, 20 gm.	.40	2		
6 weights, 10 gm.	1.08	6		
1 siren disk	1.10	1		
1 Newton's color disc	.60	1		
1 dew-point apparatus	1.00	1		
1 air thermometer bulb	.20	1		
6 zinc elements	.30	6		
1 glass tube, with stoppers	2.00	1		
1 metric chart	2.00	1		
1 calorimeter	3.25	1		
1 electroscope	5.50	1		
1 condenser attachment	4.00	1		
2 lbs. annunciator wire, #18	2.40	2		
1 spool copper wire, #30	.50	1		
1 spool G. S. wire, #24	.35	1		
1 lb. glass tubing, 6.5 mm	.70	1		
2 beakers, 2000 cc	2.00	2		
2 beakers, 1000 cc	1.08		2	
1 aluminum screen	.25	1		
24 metric rulers	2.00	24		
1 bell jar	3.25	1		
1 spectra slide	2.00	1		
1 balance scale	12.00	1		
1 specific gravity support	1.50	1		

TABLE XXIV. (Continued)

2 connectors	$ .24	2		
Total	$166.69	$149.02	$10.52	$7.15

TABLE XXV

Summary Of Loss In Physics Equipment

School	No. of Years in Period	Per Cent of Equipment Still in Use	Average Loss Per Year
A	6	75.0	$6.12
B	3	91.2	3.30
C	3	81.2	5.75
D	3	76.7	1.35
E	3	98.2	2.27
F	3	86.8	3.71
G	1	91.5	1.42
H	4	76.0	9.91
I	5	90.1	3.53
	Average	85.2 %	$4.15

The loss in physics equipment as shown in Tables XVI to XXIV is summarized in Table XXV. The per cent of equipment purchased that was still in use at the close of the period varied from 75 per cent to 98.2 per cent and averaged 85.2

per cent. The average loss per year ranged from $1.35 for the lowest to $9.91 for the highest. The average yearly loss per school was $4.15.

IX. SUMMARY

As has been stated in Section II, the purpose of this study is to determine the existing conditions in the physics laboratories in our secondary schools. The physics laboratories were surveyed for the purpose of learning if the cost of physics in the secondary school is excessive, and how closely the laboratories meet the state recommendations.

Physics laboratories are important in that they give the pupil a chance to get information first hand. Through laboratory exercises, he can develop a desire to learn more about the forces of nature around him. Everyday phenomena get to have a meaning for him and he learns that things do not just happen, but are brought about by never failing laws of nature.

The trend is away from separate laboratories for the specialized subjects and a growing preference is shown for science work of a general nature. The combined laboratory, demonstration, and recitation room was used by all but one of the schools used in the study. The size of the physics laboratory varied from 18 feet by 20 feet to 24 feet by 30 feet.

Laboratory work calls for electricity, gas, and water. All of the laboratories had electricity, the number of outlets varying from four to twenty-six. Two of the laboratories used gas for heating purposes, two used electricity, and five used other sources of heat, mostly blow torches. All of the laboratories had a supply of running water, either at the laboratory tables, the demonstration desk, or at the side of the room.

Thirty-five out of the forty laboratory tables in the physics laboratories were of standard size. Most of these had uprights. Only one laboratory in the county had running water for the individual tables.

The provision for general storage rooms is on the decrease, and specific space provision for the various kinds of supplies and materials used in the different types of work is the popular plan today. To keep the physics equipment in good condition it is necessary to have ample storage space. Only three physics laboratories in the county had store rooms. Most of the apparatus was kept in wall cases. The number of wall cases in the laboratories varied from one to four. The total amount of storage space varied from 66 cubic feet to 5592 cubic feet.

There is quite a variation in the amount of individual apparatus in the physics laboratories. The lowest school had only thirty-three per cent of the equipment recommended by the state department of education, and the highest had three hundred per cent. The average amount of individual equipment in the laboratories was one hundred twenty-eight per cent. Most of the laboratories had most of the required individual apparatus. Five of the nine laboratories had between ninety-two per cent and one hundred eleven per cent of the amount recommended.

There seemed to be quite a deficiency in teacher demonstration desks. Only four of the nine laboratories were supplied with these desks. Of these four, three had running water, electricity, and a source of heat.

The amount of recommended demonstration equipment in the laboratories was small. One school had only 23 per cent of the equipment recommended. The highest was 118 per cent. The average amount of equipment was only 59.3 per cent of the amount recommended.

Some physics laboratories had no home-made apparatus whatever, while in others a large amount of the equipment was home made.

The amount of tools in the laboratories ranged from 30 per cent to 100 per cent of the quantity recommended. The average for all the laboratories was 73.3 per cent.

The general stock of equipment in the physics laboratories varied from 40 per cent to 133 per cent of the amount recommended. The average amount in all the laboratories was 84.4 per cent.

The loss in physics equipment is for individual and general equipment, tools, and general stock. The average loss per year ranged from $1.35 to $9.91. There were only three schools in which the loss was over $5.00 a year. The average yearly loss was $4.15.

X. APPENDIX

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