1953

Determination for the modal age level for the grades IV and VI of the difficulty of the principle: "The amount of momentum possessed by an object depends upon its weight and speed of motion.

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Determination for the Modal Age Level
for the Grades IV and VI of the Difficulty of
the Principle: "The Amount of Momentum Possessed
by an Object Depends Upon Its Weight and Speed
of Motion."

Submitted by

Walter S. Perkins
(A.B., Northeastern University, 1949)

In Partial Fulfillment of the Requirements for
the Degree of Master of Education
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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Justification</td>
<td>4</td>
</tr>
<tr>
<td>Design of the Experiment</td>
<td>13</td>
</tr>
<tr>
<td>Scope and Limitations</td>
<td>13</td>
</tr>
<tr>
<td>Discussion of Procedure</td>
<td>15</td>
</tr>
<tr>
<td>II. SURVEY OF RELATED LITERATURE</td>
<td>25</td>
</tr>
<tr>
<td>Teaching By the Use of Principles</td>
<td>25</td>
</tr>
<tr>
<td>The inductive method</td>
<td>25</td>
</tr>
<tr>
<td>The deductive method</td>
<td>26</td>
</tr>
<tr>
<td>Some results</td>
<td>28</td>
</tr>
<tr>
<td>The Lecture-Demonstration Method of Teaching</td>
<td>30</td>
</tr>
<tr>
<td>The Effectiveness of Lecture-Demonstrations</td>
<td>30</td>
</tr>
<tr>
<td>The Criteria for a Good Demonstration</td>
<td>42</td>
</tr>
<tr>
<td>Statement of the problem</td>
<td>42</td>
</tr>
<tr>
<td>Need for research</td>
<td>42</td>
</tr>
<tr>
<td>Definition of demonstration</td>
<td>43</td>
</tr>
<tr>
<td>Review of the literature</td>
<td>46</td>
</tr>
<tr>
<td>Use of criteria</td>
<td>52</td>
</tr>
<tr>
<td>Selected criteria</td>
<td>52</td>
</tr>
<tr>
<td>The Test Technique</td>
<td>56</td>
</tr>
<tr>
<td>Structure of the Test</td>
<td>56</td>
</tr>
<tr>
<td>Multiple choice items</td>
<td>56</td>
</tr>
<tr>
<td>Levels of difficulty</td>
<td>57</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>59</td>
</tr>
<tr>
<td>The test tryout</td>
<td>59</td>
</tr>
<tr>
<td>The test period</td>
<td>60</td>
</tr>
<tr>
<td>Aims and Use of the Test</td>
<td>61</td>
</tr>
<tr>
<td>Employing statistics</td>
<td>61</td>
</tr>
<tr>
<td>Test-retest method</td>
<td>62</td>
</tr>
<tr>
<td>What the test endeavors to determine</td>
<td>62</td>
</tr>
<tr>
<td>Characteristics of the Test</td>
<td>63</td>
</tr>
<tr>
<td>Reliability</td>
<td>63</td>
</tr>
<tr>
<td>Validity</td>
<td>64</td>
</tr>
<tr>
<td>CHAPTER</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>------</td>
</tr>
<tr>
<td>III. EXPERIMENTAL PROCEDURE</td>
<td>65</td>
</tr>
<tr>
<td>Preparation and Operation of the Demonstration</td>
<td>65</td>
</tr>
<tr>
<td>Preparation of the Test</td>
<td>67</td>
</tr>
<tr>
<td>Schools Visited</td>
<td>68</td>
</tr>
<tr>
<td>Administration of the Pre-test</td>
<td>68</td>
</tr>
<tr>
<td>Handling of the Statistics</td>
<td>70</td>
</tr>
<tr>
<td>IV. ANALYZING THE TABLES</td>
<td>80</td>
</tr>
<tr>
<td>V. CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH</td>
<td>82</td>
</tr>
</tbody>
</table>

**APPENDIX**

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEST ON MOMENTUM</td>
<td>84</td>
</tr>
<tr>
<td>ANSWER SHEET</td>
<td>88</td>
</tr>
<tr>
<td>DIRECTIONS</td>
<td>89</td>
</tr>
<tr>
<td>LECTURE ON MOMENTUM</td>
<td>90</td>
</tr>
<tr>
<td>PHOTOGRAPH OF THE FACETS OF THE DEMONSTRATION</td>
<td>93</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>94</td>
</tr>
</tbody>
</table>
LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>The Frequency of Mention of the Selected Criteria by the Sources Consulted</td>
<td>64</td>
</tr>
<tr>
<td>II.</td>
<td>Performance of Different Mental Age Groups on Test of Momentum for the Total Population</td>
<td>77</td>
</tr>
<tr>
<td>III.</td>
<td>Means and Standard Deviations of the Pre-test for the Fourth and Sixth Grade Experimental and Control Groups</td>
<td>77</td>
</tr>
<tr>
<td>IV.</td>
<td>Means, Standard Deviations, and Proportion Passing on the Pre-test and the Post-test for the Fourth and Sixth Grade Control Groups</td>
<td>78</td>
</tr>
<tr>
<td>VI.</td>
<td>Means, Standard Deviations, and Proportion Passing on the Pre-test and the Post-test for the Fourth and Sixth Grade Experimental Groups</td>
<td>79</td>
</tr>
</tbody>
</table>
CHAPTER I
INTRODUCTION

1. Introduction

The grade placement of scientific principles has been undertaken by the Boston University School of Education, Science Department, as a project to be carried on through the succeeding years under the direction of Dr. John G. Read. The experiment will be concluded when enough pupils and schools have been included in the study to make the conclusions statistically significant. As more data are accumulated, the extent to which the study will have to be carried should become apparent. When a sufficient number of principles has been tested a complete overall report can be written giving the conclusions. That is, there will be a 'percentage of learning' index for each principle for each modal mental age level. From this index it should be possible to ascertain that if a certain principle is taught to a certain modal mental age level then a certain percentage of the pupils can be expected to learn the principle.

This year both the background for the study and the design of the experiment are being done under the guidance of Dr. Read and Mr. Herbert Oxendine. Also, the first group will start the experiment with each experimenter taking one principle. The teaching method will be a lecture-demonstration. The amount of learning will be measured by identical tests given before and after the lecture-demonstration. Data to be gathered will consist of the test scores, the pupil's I.Q., M.A., C.A., sex, previous science instruction and science background.
The results to be found by each individual participating in this study will be for only one or two grades in several schools. This will give an indication of the next grade that should be tested depending upon the 'percentage of learning' for that modal mental age level.

As the study proceeds investigation into these principles will be continued and others started until there is an index of the 'percentage of learners' for each modal mental age level for each principle. Each experimenter starting a new principle will leave his material for many teachers-in-service to use when he is finished. This will include the demonstration, a copy of the script, a tape recording of one of the actual lecture-demonstrations and the test. The same material will be used throughout the study for the same principle. The sample of schools will be chosen each year so that complete coverage may be made of each socio-economic level for grades 3-12.

It is assumed for this study that there will exist a difference in the percentage of learners at different mental age levels. It is also assumed that the time spent in a good demonstration with a carefully prepared talk would produce a small increment of learning.

The committee whose responsibility it was to compile the data included in the literature as background for this study consisted of the following members under the chairmanship of Norman G. Mills:

Isabel L. Bouin
John T. Callahan
James Creighton
Wallace J. Gleekman
Eugene H. Goldrick
George F. Griffin
Robert H. Jackman
Eleanor Kancevitch
John G. Minot
Henning A. Sahlberg
Vincent J. Silluzio
Schuyler G. Slater
Virginia M. Wilson
2. Justification

Very little scientific evidence is available on the grade placement of science principles. Because of the great increase of scientific knowledge, educators emphasize the need for research that will determine the age levels at which science concepts, principles and skills may be introduced into the curriculum with optimum effectiveness.

Beck \(^1\) states that because scientific knowledge is accumulating at such a rapid rate, there is neither time nor excuse for teaching the elementary scientific concepts in the higher grades. He points out that the scientific background and foundation prerequisite to an understanding of the individual science courses offered in the high schools are lacking in the beginning students. To find a solution to this problem, he suggests that research be started to determine, '

...what fundamentals of science can we expect most children of similar ability and cultural background to master at each maturity level'. \(^2\)

From a Progress Report of the Committee on Research in Elementary Science for the National Association for Research in Science Teaching, Venill \(^3\) believes that with the great expansion

\(^1\) Alfred D. Beck, 'Some Unanswered Questions Pertaining to the Organization of a Twelve Year Science Sequence', *Science Education* (April, 1948), 34:176-177.

\(^2\) Ibid., p. 177.

\(^3\) John Venill, 'Needed Research Studies in the Junior High Schools', *Science Education* (April, 1948), 32:175-185.
of scientific knowledge, concepts which previously have been reserved for high school science courses will have to be taught in the junior high schools. He summarizes that, "...studies should be made on pupil readiness for more advanced science concepts." 1

In the *Thirty-first Yearbook* the National Society for the Study of Education 2 suggests that a twelve-year sequence of science be taught, based on the broad generalizations of science. As an outgrowth of this plan, many problems for research were recognized. Morrison 3 places the selection and sequences of courses within the curriculum and the grade placement of topics at the top of a list of needed research in science teaching.

However, research on the location of curricular material in science classes is complex. In order to make such studies objective and meaningful, educators, says Bellack, must take into consideration the basic findings from the fields of educational philosophy, sociology, child growth and development and psychology of learning. 4

The writer believes that the aim of education is to give some meaning, some security and purpose in life. Ideally, education should provide an understanding of the diversity and richness of the present-

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1/ John Verrill, *op. cit.*, p. 175.


3/ Ibid., p. 354.

day world and take into account our uncertainty on ideas of life and the universe. More specifically, science education seeks to teach effectively those principles and skills of science which touch so largely upon everyday life. The aims of science teaching are contributory to the aims of education, mainly, as Bellack says, "life enrichment." 1/

In our society great emphasis is placed on education. Laws compel schooling up to a certain age, and all children are assured a free education. It is the school's responsibility both to society and to the children to present those activities which will prepare the individual student to participate intelligently in our democratic society.

Bellack2/ further says, "In planning the sequence and placement of school experiences, then, consideration must be given at every stage to the demands of society in regard to both the important responsibilities of citizenship and the great variety of learnings and adjustments occasioned by circumstances peculiar to our culture."

In part, grade placement of curricular material is a matter of providing experiences at each grade level which are suitable to the maturity level of the students and are designed to achieve the objectives of the program.3/ Kingsley defines maturation as "... the

1/ Arno A. Bellack, op. cit., p. 42.
2/ Ibid., p. 623.
3/ Ibid., p. 625.
normal physical growth of the physiological functions. If these physiological structures have not developed to the point where the child can carry on the activity essential for a particular kind of learning, it is quite obvious he will be unable to achieve success in this direction.\textsuperscript{1}"

In order to obtain the maximum efficiency in learning, maturation of the child must be considered carefully. Hilbreth\textsuperscript{2} points out that if a child is presented with a problem which is beyond his maturity level, he will reduce or simplify the problem to his own realm of understanding which may lead to misconceptions and make learning more difficult when the proper maturation level is reached. Washburne\textsuperscript{3} points out that if a child is presented with a problem above his maturity level with the implication that he should succeed, it will give him a feeling of failure and undermine his security. "Instead we must guide him into those learning situations that he can attack effectively and with sufficient success to yield satisfaction, encouragement and growth."\textsuperscript{4}

Many of the studies that have attempted to assign learning experiences to definite maturity levels have been concerned with motor-skill development in pre-school children.\textsuperscript{5} But a number of studies have


\textsuperscript{2} Gertrude Hilbreth, "The Difficulty Reduction Tendency in Perception and Problem Solving", The Journal of Education Psychology (April, 1941), 32:305-313.


\textsuperscript{4} Ibid., p. 3.

been made to determine the role that maturation plays in the development of various concepts, among them that of Pistor 1/ who conducted an experiment to determine how time concepts are acquired by children. Two groups of 320 children were used in the study. In grades four and five, traditional separate courses in geography and history were taught to one group while the second group was taught geography as a major course and history incidentally. In the sixth grade the first group was given instruction with special attention placed on time charts, time lines and other teaching aids. The other group had regular instruction with no special importance placed on time concepts. Through analysis of test results at the completion of the sixth grade, it was found that the group with special instruction gained slightly, but not significantly, in time-concept understanding, over the group without special instruction. Pistor concludes that "...evidence points heavily in favor of maturation rather than training as the dominating factor in time-concept development." 2/

Piaget 3/ attempted to assign stages in the child's thought development to maturity levels. Through personal interviews, questions were asked relating to the child's ideas of the causes of natural phenomena.


2/ Frederick Pistor, op. cit. p. 111.

The responses were then placed in categories developed by Piaget. For example, Piaget traced three steps in concept development relating to the origin of the sun and the moon. The first step was that of artificiality of that the sun and moon were made by some human being. The second step was a belief that the sun and moon were developed by a combination of artificial and natural causes. The third stage in this development was the belief in a completely natural origin of the sun and the moon. The implication was that the child passed from one stage to another only when he had reached the proper maturity level. Due partly to the complexity and the subjective nature of interpreting the responses of the children, Piaget's method has been criticized and his conclusions challenged.

Deutsche conducted a study at the University of Minnesota in another attempt to trace the development of concepts of causal relations in children. Identical demonstrations and tests were given to children in grades three through eight. Three experts familiar with Piaget's work attempted to classify the answers to the test items into Piaget's categories. There was little agreement among the jury as to where each response should be placed. It was found that there was a great deal of overlapping, that most kinds of answers were found over the entire age group and that the answers of children of a given age group could not be classified into a single type. Deutsche

concluded that "Causal thinking apparently does not develop by stages but by a gradual process." She also found that the adequacy of the answers to the test questions increased with age, and the greatest increase noted was between the ages of 11 and 12 years.

Haupt sought to gather evidence to find out if young children were capable of the mental activities associated with the "large generalization" type aim. His study was limited to grades one through six. Haupt found that the ability to generalize prevailed at all grade levels, but that this ability was limited by the complexity of the concepts studied.

Croxton's study also indicates that children in the higher primary, the intermediate and the junior high school are capable of generalizing.

However, grade placement of curricular material is not entirely a matter of maturation. It is a matter of learning readiness which includes maturation, experiential levels, interest and attitudes, social pressures and training. But these factors are extremely difficult to separate for study. In the human body every organ is an integrated

1/ Jean Deutsche, op. cit., p. 93.
2/ Ibid., p. 29-42.
part of the whole body. If one organ is malfunctioning, it will affect
the normal activity of the whole organism. Similarly, the child is a
composite of many factors, each affecting the functioning of the other.

All experiences, according to Dewey,¹ both take up something
from those which have gone before and modify in some way the
quality of those which come after. West² says that it is useless
to show that a given volume of warm air is lighter than the same
volume of cold air before the concept that air is something that
has weight and occupies space is understood. So while the pupil
may be at the maturity level for understanding a certain concept,
if the necessary background is lacking, he will not learn effect-
ively. Even if the maturity and experiential levels are adequate
for learning, lack of interest or proper attitudes, inadequacy of
teaching method and materials may account for unprofitable learning.

This study is designed to establish a learning index of the
various scientific principles. This learning index will indicate the
approximate mental age level at which these principles can be
taught effectively to children of similar ability and background. Be-
cause of the complexity of the learning process, absolute values as
to where each principle should be included in the curriculum is not

¹/John Dewey, Experience and Education, The Macmillan Co., New
York, 1938, p. 27.

²/ Joe Young West, "Do We Expect Too Much or Too Little of Children
From Their Experiences in Science?" Science Education (Oct. 1944),
33:298.
expected, but the results may prove helpful to curriculum planners in determining the grade placement of these principles. The results of this study will be of importance to classroom teachers, textbook writers, standardized-test makers, and producers of visual-aids. It may, moreover, help bring about an orderly, systematic teaching of science, resulting in more and efficient learning.
3. Design of the Experiment

A. Scope and Limitations

The objective of this study is to establish a learning index for a number of scientific principles both in the elementary and secondary grades, the total study being made over a period of approximately ten years. An index of learning is to be assigned to each level at which the experiment is carried out.

A beginning has been made here by twenty-eight students working with different principles. Subsequent investigators using identical techniques with the same or other principles at different age levels may, after having secured data on a large number of pupils, predict with some accuracy where a certain principle might be taught with knowledge of its being understandable to the majority of pupils at that age level.

The procedure to be described is essentially the same in all the studies made by those twenty-eight investigators. However, since certain of these persons could not, of necessity, meet all of the conditions here set down because of their own teaching duties, the procedure has had to be slightly varied in such cases. Whenever any changes have been expedient, it will have been noted in subsequent chapters.

The population used in the study made by this first group of investigators is composed of pupils from the third to the twelfth grades. They are a stratified sampling of the school population of several New England states.
Each pupil's mental age is known through the use of chronological age, as furnished either by the pupil himself or the teacher, and the I.Q. obtained from the results of the administration of the Otis Quick-Scoring intelligence test. This enabled the experimenter to establish the mental modal age for each grade division of pupils tested.

The pupils whose test scores are included in the study all have mental ages within the limits of one year from the highest to the lowest. Once the modal mental age had been established, only the scores of those pupils with mental ages of plus or minus six months from the mode were selected to be included in the subsequent analysis.

Each investigator has examined two class divisions in five schools. Of the total of ten groups included, five are samples of the same grade level and the other five are samples from a different grade level which are separated from the first five samples by two years; that is, if a particular investigator chose five tenth-grade divisions, he will also have chosen either five eights- or five twelfth-grade divisions.

Two examinations have been given to all pupils included in this study. The first will be known as the pre-test and the second as the post-test. They were identical. The post-test was given within an hour after the administration of the pre-test. The time lapse between the two was occupied either by the presentation of a
demonstration serving to illustrate the particular principle being tested, in the case of what is known as the experimental group, or by reading non-relevant material by the group to be known as the control.

Strict discipline was maintained in each group in order that the pupils might not communicate with one another or be distracted from the examination or the demonstration given.

The demonstration was of large enough size, and was well lighted, so as to be seen by all the pupils in the class room easily.

B. Discussion of Procedure

The first step involved the selection by each investigator of a principle to be demonstrated and tested. Such accepted lists as that compiled by Robertson1/ were consulted.

A review of the literature established that the teaching of principles is an effective method for teaching science. It was found that facts were retained better when pupils were taught by principles. Also, relationships in applied learning were perceived more easily. Further findings on science teaching by principles are discussed in greater detail in a subsequent section.

The second step consisted in devising one or more demonstrations which illustrated the chosen principle. The time allotted for this teaching material was in most cases approximately 15 minutes. These demonstrations were necessarily simple, large, and contained as nearly as possible the "purity of concept" which has been interpreted by

Nichols to mean that the demonstration illustrates one and only one principle. But if all other principles could not be eliminated, they were judged not to lead to a misconception of the material taught.

The demonstration material of each experimenter was decided upon and the apparatus set up after having been presented to and passed on by a board consisting of a small group of investigators, who in turn, held their demonstration material up to scrutiny by fellow board members.

In a subsequent section of this thesis are discussed the criteria for a good demonstration. The eleven pertinent points are summarized as follows:

1. The demonstration should illustrate a basic principle.
2. The demonstration should illustrate one principle only.
3. The action of the demonstration should be clearly visible to all.
4. The apparatus should be on a large scale.
5. The demonstration should be simple and the speed of action suitable.
6. The demonstration should work; it should be as infallible as possible.
7. The demonstration should be dynamic.

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8. A slight dramatic element is sometimes useful.

9. An element of the unexpected is sometimes effective.

10. The apparatus should be of easily available and inexpensive material.

11. The apparatus used in a given demonstration should be stored away intact until it is to be used again.

All members of the group have adhered rigidly to these criteria.

It might be mentioned here that research, which will be described in Chapter 2, on the idea that demonstrations are effective brought to light the fact that the demonstration is equal to or better than any other method of teaching science. Thus it is seen that if a particular scientific principle can be taught at a certain age level, the demonstration method is as good a way known to aid in the teaching of it.

After having perfected the demonstration a third step in the procedure was followed. Each investigator devised a test of the four-answer multiple choice type to be administered in not over 15 minutes time. This type consisted of approximately thirty items divided into three groups. The first ten items were based directly on the demonstration to be given. The second group consisted of items which involved transference; that is, these items did not test an understanding of the demonstration directly but tested the ability to apply the scientific principle involved to other simple nearby situations. The last ten items were more difficult; they involved an application of the principle but were of such a nature that correct answers might be made by the pupils who had gotten the most from the demonstration.
All of the items were so worded that the pupil could be given this test before the demonstration had been seen and yet answer the questions if he understood the principle. For example, a question might be begun with a phrase such as "If a tight wire is plucked,......", etc.

In order to establish a suitable vocabulary for the items on the test, Thorndike's *Teacher's Word Book* was used. This volume lists words used most often in standard English reading material. Words used in the items were compared with the list to suit either the elementary or the secondary grades. If the particular words were not mentioned, others had to be substituted. The final form of the test contained a vocabulary which was suitable to the level at which each investigator was working. A copy of the writer's test is included in the appendix.

The test items were put in the interrogative form whenever practical with the answer to each consisting of one correct response and three distractors.

When the test was completed, it was presented to the same board which had previously judged the quality of the demonstration material. The items were passed if, in the opinion of the board, they were valid. An answer sheet for the test was devised whereby an enclosed space was left after the number of each item for the letter of choice.

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The fourth step in the procedure involved the administration of the test to approximately one hundred pupils of the same grade level as the pupils for which it was finally intended. The results were incorporated in an item analysis which is described in a later section of this thesis. Any items which were shown not to be serving especially well were left on this final form of the test but only those items which were functioning well were used in subsequent compilations.

As the fifth step, a script to accompany the demonstration was written by each investigator using a suitable vocabulary selected from Thorndike’s word list. This was not to be read to the experimental group while the demonstration was shown but served as a guide for the demonstration lecture, key points of the written procedure having been committed to memory by the experimenter. This minimized the probability of the individual lectures varying widely from day to day.

The investigator then presented his lecture and demonstration to a few pupils inviting comments after the presentation. In this manner both the script and demonstration were refined.

At this point in the procedure, the test and the demonstration were ready to be given. Each investigator had written to superintendents of schools, receiving permission to test pupils of two particular grades in each school. Altogether five schools were selected and the pupils of two grade divisions in each school were chosen as subjects for the experiment.

1/ Edward L. Thorndike and Irving Lorge, op. cit.
In some cases, investigators chose the elementary grades and in others, the secondary.

The sixth step involved the administration of the Otis Quick-Scoring intelligence test, by the investigator or the teacher of each particular division, during a period within two weeks of the demonstration.

The largest part of the experimental work is contained in the seventh step. On a prearranged date at a prescribed hour all the students of one class were pre-tested at the same time; that is, the examination was presented to the pupils before the principle was demonstrated. They were first given a test booklet and an answer sheet marked Test 1 on which there was a place for the filling in of the following information: name, sex, date of birth, name of school and town, and the previous training each pupil had in science. With regard to some of these items, in the lower elementary grades the information noted had to be checked and, many times, supplied by the teacher.

Each answer sheet contained a random number in the upper right hand corner and also a place for the investigator to later fill in any information he desired such as socio-economic background, I.Q., etc. A sample answer sheet is shown in the appendix.

The time allotted for the pre-test was approximately fifteen minutes. At the end of this time the answer sheets were collected and half of the pupils in the class were sent to another room, after handling their test booklets to the demonstrator or the teacher in charge. The remaining half kept their booklets and stayed in the room to see the demonstration.
Half of the pupils were randomly selected according to a method used by Lindquist. A table in his book was consulted and utilized. To explain the use of the table, it is perhaps expedient to use a hypothetical class in a single run of the experiment. Since there are 36 pupils in this class and half are to be selected at random, 18 pupils must be chosen arbitrarily. The first step is to assign numbers from 00 to 35 to the 36 answer sheets. This may be done in any order. Then it is necessary to select a starting point on the table by referring to a column and row number. As Lindquist states,

"This starting point should be determined before looking at any number in the table. Once having selected the starting point and direction, no peculiarity in the numbers read should be permitted to cause one to disregard the results and start anew at another point."

From the starting point and reading in the chosen direction, the first 18 unlike numbers below 36 are taken and the pupils previously assigned these numbers are then one of the halves of the class.

After the class was divided, the answer sheets for the pre-test were collected and half the class was removed, as stated above. This half was designated as the control group. They spent the next 15 minutes reading silently some non-science material in another room.

Up to this time, the demonstration apparatus, which had been previously placed in the room where the pre-test had been given, was kept covered with a cloth. With only half the original group present, these demonstration

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materials were uncovered and the investigator began his experiments with his accompanying remarks of explanation.

When the demonstration, having lasted approximately 15 minutes, was over, a post-test answer sheet marked Test 2 was distributed to each pupil. This sheet was the same as that for the pre-test with the exception of the identifying test number. The original closed test booklet, which was to be used for the post-test, had been placed in the upper right hand corner of each pupil's desk. The group had previously been cautioned by the demonstrator not to open the booklets or talk among themselves while he was experimenting.

The post-test, being identical to the pre-test since the test booklet contained only the one test, was then administered to this experimental group. At the end of the allotted 15 minutes, the booklets and both answer sheets were collected.

Meanwhile in the room to which the other half of the class, the control group, had moved, the same post-test was given as was administered to the experimental group by a teacher who also supplied the pupils with an answer sheet marked Test 2 and a test booklet. After about 15 minutes had elapsed, the papers and booklets were collected.

In the cases where the investigator was working with elementary grade school pupils, the demonstration was given to the control group after they had taken the post-test because of the interest they undoubtedly had, because of administrative reasons, and, more important, because the time element was not such an important factor as it was in the secondary school where the control group was not given the demonstration.
This same procedure was repeated with individual divisions in each school until, as mentioned above, data on a total of ten divisions in five schools was collected.

It has been found that a reliable method of measuring the amount of learning of some specific activity, is by means of the test-retest method. By using the test-retest method, the level of previous knowledge concerning the activity may be established. Using this information any gain in knowledge can be easily established. A detailed section on the test technique will be found in the next chapter.

The eighth step in the experimental procedure involved the compilation of statistics using the scores on both the pre-test and post-test, the group modal mental age which had been computed from the I.Q. and the chronological age of each pupil. As was stated above only the scores of those pupils with mental ages of plus or minus six months from the mode were included in the statistical analysis. If a pupil of the experimental group showed a lack of understanding of the questions relating directly to the demonstration on his post-test, his scores were excluded from the analysis. A score which was less than 80 per cent correct on this part of the post-test was not used. The second chapter of this thesis contains a detailed explanation of how the scores were handled statistically.

The ninth and final step of the procedure was the making of a tape recording using the previously refined script for the demonstration lecture. When this had been done and the resulting recording found
satisfactory, it was packaged along with the test booklets, sample answer sheets, and the demonstration material. In this way, all necessary information and equipment will be ready for future investigators using the same principles.
CHAPTER II
SURVEY OF RELATED LITERATURE

1. Teaching by the Use of Principles

The teaching of science by principle rather than by extraneous collections of facts has been generally accepted by educators. The Thirty-first Yearbook of the National Society for the Study of Education, says that life enrichment, the aim of education, can best be achieved if the schools activities are "of the kind from which ideas may be developed and if the ideas may in turn be associated into principles and generalizations that are interwoven into human experience. Functional learning is conditioned upon attainment of some such integration."\(^1\)

Hoban says: "Education is not simply the accretion of information. It involves the fundamental knowledge and the understanding of the basic principles of the universe, of which man is a part."\(^2\)

The inductive method.—Here the learner arrives at a general conclusion, e.g. certain laws of physical sciences, by examining a number of individual cases. The weakness in this method is that there is a possibility of too general a conclusion, as the enumeration of particulars can never be totaled. For example after several enumerations of plants having flowers such as, the cactus has a flower; the buckwheat has a flower; the stringbean


\(^2\) Charles F. Hoban, Focus on Learning, American Council on Education, Washington D.C., 1942, p. 34.
has a flower; we might conclude all plants have a flower. This is too
general a conclusion as there are active fungi which do not possess
flowers. Induction is thus essentially imperfect as a mode of reasoning,
though invaluable as a means of fixing general principles and laws amid
the succession of particularities given in experience.  

The deductive method.—The learner reasons from a principle to a
particular. It is in this method that we shall be mainly interested, for
we are basing our whole experiment on the reasoning powers of the learners
to go from the principle to a particular inference to the principles in
their learning process. For example: If a learner understands the
principle of friction he can deduce that heat is released and wear between
the surfaces takes place when one body is rubbed over another.

A large amount of our teaching attempts to pupils to see the implication
of the laws, principles and rules that they may have learned. As
contrasted with induction, deduction is a much simpler and shorter process.
It is an unusual situation when a bit of deductive teaching lasts longer
than a few minutes.

Advantages of deductive educative teaching:

1. Much more simple than the inductive method
2. Results in very desirable outcomes
3. Introduces factors of organization
4. Makes meaningful the principles that have
   been mastered already
5. Arouses puzzle or questioning instinct, a
   very valuable aid

6. Helps pupils to derive their principles from books or demonstrative techniques. 1/ 

Jones, 2/ Leonelli, 3/ Martin 4/ and others have emphasized the value of teaching science by principle, and have listed hundreds of principles.

However, there is some disagreement as to what constitutes a principle. Heinmann defines a principle as "a statement of relationship between two or more facts." 5/

Wilbur's definition as stated by Martin 6/ is much more precise and makes a principle a very specific kind of generalization. His criteria state that a principle -- 

"Is stated positively and definitely 
Is true but with rare exceptions within the limitations set up by the statement 
Clearly states or implies a dynamic process or interaction 
Is demonstratable experimentally 
Is clearly not a part of a larger principle which can be clearly stated 
Is not merely a definition or description 
Has wide application in the natural environment and is not ruled out by any of the preceding criteria."


Robertson's definition of a principle was the result of many weeks of consideration by a seminar in science teaching under F. D. Curtis at the University of Michigan:

"a. To be a principle a statement must be a comprehensive generalization
b. It must be true without exception within limitations specifically stated
c. It must be a clear statement of a process or an interaction
d. It must be capable of illustration so as to gain conviction
e. It must not be a part of a larger principle
f. It must not be a definition
g. It must not deal with a specific substance"

With this definition, Robertson sought to determine a comprehensive list of principles suitable as goals of instruction for elementary schools. He evaluated nine separate studies listing principles found in textbooks, arranged according to frequency and stress, by a jury of three science teachers and several subject matter specialists. A list of the 243 principles found was sent to fifteen elementary school science teachers and from their ratings 113 principles were chosen. These are the principles used in the present study.

Some results.—There is considerable evidence that scientific principles can be taught effectively to students at the secondary level. Freud and Cheronis readministered a comprehensive test to students of a survey course in physical science one year after the course had been completed. They found that principles and the ability to apply such

principles were retained much better than were unrelated facts. 1/

Babitz and Keyes paired eight classes in chemistry in two California High Schools. Four of the classes, designated as the control groups, received standard instruction; the other four designated as the experimental groups, had direct and intensive training on the application of principles. The tests administered at the end of the experiment required the solution of problems in chemistry and the identification of scientific principles related these two. All the experimental groups showed superiority over the control groups in the same schools. The differences however were not statistically significant. 2/Kilgore paired 120 students in high school physics with respect to their previous experience in science courses studies and I.Q. He found at the end of his study that students of both high and low ability were significantly better in making applications of principles of physics when the instructor placed emphasis on such application. 3/

The evidence from these studies seems to indicate that the learning of principles of science, and the ability to apply them, may be attainable

1/ Henrietta Z. Freud, and Cheronis, N. D., "Retention in the Physical Science Survey Course", Chemical Education Journal (June, 1940), 18:288-293


objectives of the teaching of science at the secondary level provided such objectives are emphasized in instruction.

2. The Lecture-Demonstration Method of Teaching

A. The Effectiveness of Lecture-Demonstrations

The areas which will be treated in this section are to define and describe the term lecture-demonstration, and then to quote freely the written opinions of science educators with regard to the use of demonstrations in science teaching, describing the psychological and logical basis for the use of demonstrations in teaching. Then, a review of the research in which the lecture-demonstration is compared with other methods of science teaching will be presented.

Before discussing desirable qualities in a demonstration, Mack, in describing and defining a demonstration, says in part:

"Inherent in the concept of demonstration is the factor of movement of a material thing, not a static condition or display. A demonstration is an appeal through the senses of sight and of hearing, and less frequently through the other senses. Results must follow the purpose; there must be conviction, compelling to an inescapable conclusion."

Regarding lecture-demonstrations, Stuit and Englehart express their definition by stating:

"The term lecture-demonstration is used to describe a method of teaching in which the teacher carries out a demonstration for the entire group and lectures in parallel with it. The students observe the demonstration and ask any questions which they desire about the demonstration or theory involved."


Any discussion of the use of the demonstration in science teaching should be related to certain principles of learning. Potthoff\(^1\) has expressed awareness of such a relationship in the following writing:

"The use of the concrete, particularly where it deals with the unfamiliar, can provide an experimental basis for learning, whether that learning be remembering facts, understanding processes, seeing relationships, or getting an idea of how motor skills are executed. Direct experience, especially if it is with the unfamiliar, may motivate the learner, attract his attention, stimulate his interest, and arouse his curiosity. Demonstrations can be helpful also in facilitating comprehension of the abstract, giving reality to the spoken word, and reinforcing it by providing impressions through several sense avenues. In general, learning may be more meaningful, more accurate, more complete, and more permanent if it is based upon actual experience with that which is being studied."

Additional emphasis on the importance of the real or direct experience in learning has been made by Richardson and Cahoon in Methods and Materials for Teaching General and Physical Science\(^2\). They stated that:

"Probably the most usual use of the demonstration is for illustrating and explaining scientific principles and their applications. For most students seeing the real thing is much more helpful than reading about it or looking at a picture of it."

Whether the demonstration precedes or follows activities such as discussion, reading, films, and laboratory work, it may not automatically provide an understanding; but it furnishes a real experience upon which the teacher may build, along with other well-chosen procedures and activities.


Demonstrations can be used for providing pupil experiences in thinking. Cahoon's\(^1\) views on this topic are, in part, these:

"The demonstrations, laboratory experiments, directed studies, pupil projects, motion pictures, textbook statements, and pupil-teacher discussions are teeming with possibilities for pupil experience in thinking. It is largely a matter of utilizing these appropriately as one goes about teaching science facts and principles to pupils.

Like any other teaching aid or pupil activity, a particular exercise or experience in thinking may or may not be appropriate to use with a particular class at a given time.

A certain demonstration for one class may be given to help obtain a particular fact of science, at another time as an experience in accurate observation, at another to utilize previous knowledge by predicting 'what will happen', at another as an application of a recently studied principle."

However, it must be added here, that "A demonstration performed by a teacher who points out what is happening and indicates the conclusion which should be drawn or how it illustrates a particular principle may furnish little experience in thinking."\(^2\) However, "thinking" comes when the principle is applied.

Before presenting a review of the research in which the lecture-demonstration is compared with other methods of science teaching, the evolution of the popularity of the demonstration method should be mentioned.


\(^2\) John S. Richardson and G. P. Cahoon, op. cit., p. 67.
Webb states that it developed in this manner:

"The growth of the demonstration method as a substitute for the individual experiment was accelerated by the depression, during which time funds for operating the schools were much reduced. It was argued that if the course in science be given by demonstrations, only one set of apparatus need be procured; whereas if it were given by student individual or group experiments a considerable number of duplicate sets must be purchased."

Cunningham's summary of "Lecture Demonstrations Versus Individual Laboratory Method in Science Teaching" covers a twenty-five year period. The field of research includes eighteen Master's Theses, six Doctorate Studies, and other studies. All of the reports were published in such professional periodicals as: Journal of Educational Psychology, School Science and Mathematics, School Review, Journal of Educational Research, and Pennsylvania School Journal. From the results reported by the experimenters, Cunningham states that:

"Twenty-eight studies gave specific attention to the general outcome – immediate recall or immediate results. Twenty gave results favoring the demonstration method; six favored the individual laboratory method; and two said that there was no difference between the two methods.

Of the twenty-four studies that gave specific attention to delayed results, ten favored the demonstration method, eleven the individual laboratory method, and three reported no difference.

The interest stimulated in the pupils by the two methods was studies in seven of the enterprises. The majority of the pupils in three of the enterprises favored the

3/ Ibid., p. 76
demonstration method; and in four out of the enterprises favored the individual laboratory method.

All of the studies - fifteen - that gave attention to the time required by each of the two methods reported a saving of time under the demonstration method. The time saved varied from one-fifth to one-half."

Later in the summary, Cunningham tells of the treatment of scientific thinking in these studies by these comments:

"Seventeen studies gave attention to one or more of the elements of scientific thinking but no one undertaking made even a slight beginning in the study of this problem in all of its many aspects. The elements of the thinking process that were studied in some of the undertakings were as follows: amount retained in thought work; making proper conclusions to an experiment; application of principles learned; ability to think in terms of science subject; ability to follow the steps in scientific procedure; per cent of thought questions answered correctly; method of attack on new problems; scientific attitude; ability to observe; learning a scientific principle; greater carry-over ability; ability to distinguish between fact and superstition; and ability to generalize.

Of the seventeen studies that gave attention to some phases of this big and very important problem, twelve favored the demonstration method; four the individual laboratory method; and one came to the conclusion that the pupil could learn to think about equally well by either method."

This comprehensive statement is part of the concluding remarks made by Cunningham:

"Our decision, as to what to do in practice, is made easier when we realize that all of our laboratory teaching need not - should not be done by one method. It is possible that we may be ignoring a whole continuous series of possibilities between these two extremes. In many cases it may be found best to use both methods in teaching a given idea in science."

The studies presented in the summary of Cunningham were ranked according to the criteria presented in an article by Stuit and Englehart.

1/ Op. cit., p. 76
2/ Ibid., p. 79
by Keiser\(^1\) as to their superior or inferior value. It is well to note here that Keiser used only the first six of the seven criteria to determine the value of these studies. The seven criteria, as established by Stuit and Englehart, are as follows: (1) specification of experimental factors; (2) control of pupil factors; (3) control of teacher factors; (4) control of general school factors; (5) duration of experiment; (6) measurement of achievement; and (7) interpretation of experimental date.

For comparative purposes the writer has used the studies of Anibel\(^2\), Knox\(^3\), and Wiley\(^4\) in this discussion because each study is partly concerned with the demonstration method versus the laboratory method of teaching high school chemistry. The problem of the research as stated by each author and the significant conclusions, in part, will be related.

The study of Fred G. Anibel\(^5\), ranked superior, is as follows:

Problem: To determine scientifically through objective data how the results of teaching high-school chemistry by lecture-demonstration method compared with the individual laboratory method.


\(^5\) Loc. cit.
Conclusions, in part:
1. The immediate retention is as adequate when material is presented by the lecture-demonstration method as when the class is taught by the regular individual laboratory procedure. Indications are that the lecture-demonstration procedure would result in better immediate retention.

2. The delayed retention is so little different that one method may be considered as good as the other. There was a slight indication that the material was better remembered when taught by the individual laboratory procedure.

3. The brighter students are likely to profit more by the lecture-demonstration method than are the others.

The study by W. W. Knox, which was ranked superior, is as follows:

Problem: To establish the relative value of the demonstration and laboratory methods of science instruction.

Conclusions, in part:
1. The demonstration method is superior to the laboratory method in teaching mentally heterogeneous groups of pupils for the purpose of immediate retention and relatively permanent retention of subject matter in high school chemistry.

2. For the purpose of imparting to a group of pupils a scientific attitude and training in a method of attack on new problems, the demonstration method is equal, if not superior, to the laboratory method of instruction.

3. From the standpoint of the coefficients of correlation, it appears that the demonstration method provides superior opportunity for adaptation to individual differences in mental ability so far as teaching for immediate retention, delayed retention, and method of attack are concerned.

4. So far as providing knowledge and method of attack are concerned, the laboratory method is slightly superior to the demonstration method in the case of the average inferior pupil.

5. For the purpose of providing knowledge for both immediate retention and relatively permanent retention, and for the purpose of providing a technique for handling new problems, the demonstration method is much to be preferred to the laboratory method in the case of the average superior pupil.

1/ Loc. cit.
Before stating the problem and significant conclusions of a study ranked inferior by Keiser\(^1\) according to the first six of the seven criteria developed by Stuit and Englehart\(^2\), it should be recognized that the study made by Wiley\(^3\) was a pioneer enterprise, being published in 1918. Probably it has been ranked as of inferior value because of the following factors: no mention is made of any attempt to measure the mental abilities of the pupils\(^4\); the tests to measure immediate and delayed retention were of doubtful validity; the method of scoring the tests was highly subjective; and there was no mention made of statistical treatment of the data found.

The study made by William H. Wiley\(^5\) is as follows:

Problem: To determine the best of the three methods of teaching chemistry, the textbook recitation method, the so-called lecture/demonstration/ method, and the laboratory method.

Conclusions, in part:
1. There is not as great a difference as is ordinarily supposed in the value of the three methods, lecture/demonstration/, textbook, and laboratory, so far as imparting knowledge is concerned.
2. For immediate learning the textbook method is unquestionably superior.
3. For permanent learning the laboratory method is perhaps slightly superior.
4. In every respect the lecture/demonstration/ method is the least effective in imparting knowledge to high school students.
5. The rate of forgetting is greatest with the textbook method and least with the laboratory method.

\(^1\) Loc. cit.
\(^3\) Loc. cit.
\(^4\) Note the date of publication of the first group intelligence tests.
\(^5\) Loc. cit.
6. The different methods show decided individual differences both for immediate and delayed reproduction.
7. Probably a combination of the three methods will give the best results in teaching high school chemistry.

Stuit and Englehart\(^1\) have also made an excellent critical analysis of the lecture demonstration versus the individual laboratory method of teaching high school chemistry. A summary of their report, which consisted of the combined conclusions of various investigators, is as follows:

Conclusions contending that the laboratory method is superior:
1. There is a slight indication that material was better retained when taught by the individual laboratory method - Anibel.
2. The order of preference of the methods studies places the individual laboratory method before the demonstration method - Horton.
3. In every respect the lecture method is least effective in imparting knowledge to high school students - Wiley.
4. For permanent learning the laboratory method is perhaps slightly superior - Wiley.
5. For providing knowledge and method of attack, the laboratory method is superior for the inferior pupil - Knox.

Conclusions claiming that the demonstration method is superior:
1. Bright pupils are more likely to profit by the lecture-demonstration method than are the others - Anibel.
2. Dull pupils profit more from demonstration than from individual laboratory work - Carpenter.
3. The lecture-demonstration takes less time and costs less - Anibel.
4. The teacher (Demonstration) method is best - Nash and Phillips.
5. Lecture-demonstration method gives better control over the individual since all are under teacher guidance - Pugh.
6. For purpose of providing knowledge for both immediate and permanent retention and for the purpose of providing technique or handling new problems, the demonstration method is much to be preferred to the laboratory method in case of average superior pupil - Knox.

\(^1\) Op. cit., pp. 388-391
Conclusions contending that the students achieve equally well by either method:

1. Immediate retention is about equal in both lecture-demonstration and individual-laboratory methods - Anibel.
2. There is not as great a difference as is ordinarily supposed in the value of the three methods, lecture, textbook - and laboratory, so far as imparting knowledge is concerned - Wiley.
3. The results of this experiment point to the conclusion that the majority of students in high-school, laboratory-chemistry classes, taught by the demonstration method, succeed as well as when they perform the experiment individually, if success is measured by instruments which measure the same abilities as are measured by these tests, namely, specific information and ability to think in terms of chemistry - Carpenter.

General conclusions based on evaluation of the reported research:

After considering the above conclusions the writers have arrived at a few ideas which seem justifiable in the light of the evidence given by this study.

1. No method can be considered to be the best in every case. The objectives of chemistry teaching, the preference of the teacher, the nature of the pupil, and the facilities of the schools will largely determine which method should be used.
2. In small schools where money and space are not plentiful the lecture-demonstration method seems to be most practicable.
3. The written test cannot be used to test all the outcomes of a course in high school chemistry. Some sort of manipulative tests seem necessary to test the laboratory skills.
4. The problem of the relative merits of the lecture-demonstration and individual-laboratory methods still seems unsolved and as complex as ever. More careful experimentation, involving careful control of non-experimental factors and reliable testing, is needed in order to justify any definite and final conclusions. When experimentation has shown the relative superiorities of the methods in terms of outcomes, the methods should be evaluated in terms of the values attached to these outcomes.

Evidence of the evolution of teaching methods particularly by the visual method is apparent in the next study to be considered, that of
Smith. The visual method has been long recognized by leading educators as one of the most valuable ways of training pupils in all stages of learning. It is difficult, as a result, to find a school that does not, in one way or another, make use of visual aids in teaching. The alert teacher and administrator are constantly seeking suggestions and illustrations by means of which the vague conceptions of the pupils may be made into real facts and parts of their experience. Any method will not be overlooked if it can provide both clarity and simplicity combined.

In the study done by Smith the problem involved was:

1. What is the relative effectiveness in ninth grade general science classes of experimental demonstrations performed by the teacher and equivalent demonstrations presented through the medium of educational sound motion pictures.
2. The determination of the relative effectiveness of these two instructional techniques with pupils of different levels of intelligence.

In the plan of study three methods of presentation were used:
(1) teacher demonstration, (2) use of films, and (3) a combination of teacher demonstrations and the use of films. The conclusions made, as a result of this study, were as follows:

1. Educational sound motion pictures and teacher demonstration are of equal merit as instructive devices in ninth grade general science when they include essentially the same materials in so far as merit can be determined.

1/ Herbert A. Smith, "A Determination of the Relative Effectiveness of Sound Motion Pictures and Equivalent Teacher Demonstration in Ninth Grade General Science", Science Education (April, 1949), 33:214-221.


by the techniques employed in this investigation. The use of either method singly is as effective as the combination of the two.

2. There is a tendency for increased intelligence as expressed in terms of an intelligence quotient to be accompanied by increased learning where learning is represented by the gain of final over initial test scores on the objective tests used in this investigation. The degree of relationship is independent of the method of instruction utilized indicating the same relative value for sound motion pictures and teacher demonstrations portraying essentially identical materials regardless of the level of intelligence of the students.

Certain similarities exist between the problem of this science seminar and the problem investigated in the study by Croxton. His problem was stated thusly:

"Is the failure of children to generalize due primarily to lack of power or tendency, or is it simply due to want of sufficient experience..."

In this study most of the experiments tested the pupils' ability to formulate and apply a principle after eight minutes exposure to the essential experimental basis in the form of a demonstration or directed play. The tentative conclusions made by Croxton are as follows:

1. The data indicates that many children in the higher primary, the intermediate, and the junior-high school grades are capable of generalizing.
2. While the experiments do not prove that most pupils in the kindergarten and lower primary grades could not generalize if a more adequate experience basis was provided, the data together with the evident obsession manifested by these children for obtaining emotional satis-

1/ W. C. Croxton, "Pupils' Ability to Generalize", School Science and Mathematics (June, 1936), 36:627-634.

2/ Ibid., p. 634
faction do suggest that early childhood is preeminently a period for satisfying reactions.

3. There is little in these experiments to suggest that junior-high school pupils possess markedly superior ability to generalize than intermediate grade pupils possess, the difference in the scores in favor of the former being little more than might reasonable be credited to added experience.

In summary, therefore, of the research and studies compiled by investigators on the value and the effectiveness of the lecture-demonstration, as compared to other methods of science teaching such as the individual laboratory method, the textbook method, and sound motion pictures, it can be concluded that the lecture-demonstration method of science teaching is equal to, if not better than, any other method of teaching. It incorporates direct experience of the pupil, pupil experience in thinking, utilization of the senses, understanding processes, application of scientific principles, and ability of the pupil to generalize. Through the use of the lecture-demonstration most, if not all, of these above qualities are satisfied. Again, the writer would like to cite the fact that the lecture-demonstration method is equal to, if not better than, any other method of teaching science.

2. Criteria for a Good Demonstration

Statement of the Problem.—There are two problems involved in developing a list of criteria for a good demonstration: (1) to define clearly the word "demonstration" as it is to be used in this experiment; (2) to evolve, through reference to the literature, the criteria.

Need for research.—Since the demonstration is the instructional procedure selected for use in the experiment, it is necessary to clarify the meaning of the demonstration method.
Noll has pointed out the fact that investigators seldom define teaching methods carefully and minutely enough. Various writers have recognized the need in research for accurate definition of terms. Like Noll, Riedel has made a plea for clear definition of teaching methods and experimental procedures. Mack has stated that there are as many definitions of "demonstration" as there are authors treating the subject. Preston also realized this and called for clarification and unification of terminology.

Most of the literature on the demonstration method fails to recognize the difference between the lecture-demonstration, the class experiment, and the illustrated lecture. Preston attributes much of the success of lecture-demonstrations to their actually being class experiments.

Definition of demonstration.—The demonstration is in this experiment actually a lecture-demonstration. Reference to the literature will help to clarify the meaning. First, the "demonstration" is defined by the


5/ Loc. cit.
Dictionary of Education¹ as follows:

"(1) The method or process of presenting or establishing facts; (2) the procedure of doing something in the presence of others either for means of showing them how to do it themselves or in order to teach a principle."

The same source² defines the lecture-demonstration thus:

"An instructional procedure in which the verbal message is accompanied by use of apparatus to illustrate principles, determine or verify facts, clarify different parts, or test for comprehension of material under discussion."

Preston³ further clarifies the concept of the lecture-demonstration as distinct from the class experiment:

"In true lecture-demonstration the teacher shows everything, explaining or interpreting each point as he, or some pupil, performs the work. In true class experimentation the teacher endeavors, by well-directed questions, to get the members of the class to observe or come to conclusions themselves as to the proper interpretation, and perhaps to plan further steps or procedures. Thus, in the lecture-demonstration the flow of information and explanation is from teacher to pupils; in the class experiment it is exactly the opposite."

Elsewhere, in defining lecture-demonstration, Preston⁴ makes the point that "no questions interrupt the speaker and he asks his audience none, other than for rhetorical effect."

Preston, however, does not distinguish the lecture-demonstration from

² Ibid., p. 238
⁴ Carleton E. Preston, "Is the Debate in Common Terms?" Science Education (February, 1935), 19:14-16.
the illustrated lecture as does the Encyclopedia of Modern Education: 1/

"The lecture-demonstration differs from the illustrated lecture in that the latter focuses attention on the screen and shows the relationships by means of pictures, slides, moving pictures or specimens while the lecture-demonstration focuses attention on the lecturer who shows the relationships through the use of manipulation of physical material, machines or appliances."

The meaning of "demonstration" is further expanded by the following observation made by Mack: 2/ "Inherent in the concept of demonstration is the factor of movement of material things, not a static condition or display." This so-called dynamic quality of the demonstration leads Mack 3/ to exclude from the demonstration procedure certain standard teaching materials:

"objects, unless they can be operated ... so also, specimens, samples and parts ... Likewise models, as such, are barred unless they are working models; so also, miniatures and enlargements."

Although micro-projection techniques are gaining increasing favor in demonstration work, 4/ it would seem that this method should also be excluded on the same basis as the other visual aids. Further, Mack 5/ states that the demonstration is "an appeal through the senses of sight and hearing and less frequently through the other


3/ Loc. Cit.


5/ Op. cit., p. 21
senses". He would, therefore, exclude from demonstration work materials that appeal to only one sense; such as, transparencies, pictures, charts, recordings and radio reproductions.

Thus certain characteristics of the demonstration have been determined by definition. These are:

1. The demonstration is an instructional procedure.
2. It is frequently used to teach principles.
3. It differs from the class experiment.
4. It differs from the illustrated lecture.
5. Movement and action are essential.
6. It is an appeal through two senses: sight and hearing.

The necessary implications of each of these statements have already been suggested.

Review of the literature.—A review of the literature was made in order to discover those basic principles which might be used as a guide in doing demonstrations.

First, a search was made to locate any previous studies that paralleled this investigation. The Bibliographic Index provided the necessary references. It was found that many investigators had subjectively listed criteria in one form or another. However, only one study, documented with references, proved similar to this one. Mack covered many of the same sources in developing his checklist for evaluating desirable qualities of demonstration apparatus. He lists as "factors" those conditions

inherent in the physical surroundings and in good techniques and as "qualities" those conditions inherent in the apparatus. Much of his research had to be duplicated in this review, but for a different purpose which called for more complete and descriptive statements.

A working bibliography was developed consisting of five types of sources: (1) professional journals and science publications, (2) methodology textbooks, (3) teaching science textbooks, (4) audiovisual texts and (5) books on experiments. The following reference sources were consulted: Bibliographic Index, Encyclopedia of Educational Research, Bibliographies and Summaries in Education, Reader's Guide, International Index, Ulvich's Periodical Directory, Vertical File Service, and the Education Index.

There was great variety in the nature of the material covered which included such items as:

1. Steps to follow
2. Desirable qualities
3. Desirable characteristics
4. Points to keep in mind
5. Rules for demonstrating
6. Suggestions for making demonstrations effective
7. Criteria
8. General discussions of the demonstration method

Works included in this study fall into four categories: (1) Those which deal with the demonstration in a general sense; (2) those from the field of biology (3) those from the field of physics (4) those from the field of chemistry.
Several of the authors in the first category, the "general", emphasize only one or a few aspects of the use of demonstrations. In discussing the presentation of example demonstrations, Cahoon indicates certain steps taken to insure effectiveness of the demonstration and emphasizes only visibility and size of apparatus. Colvin offers three cautions to be observed in class demonstrations. Hoff emphasizes only visibility and planning. Pinkus suggests the need for apparatus especially designed for demonstration purposes and stresses the factor of visibility.

A few in this same group attempt more detailed coverage. Potthoff, for example, offers several suggestions for performing demonstrations effectively and contributes many excellent ideas. In discussing the art of lecture table demonstration, Davison mentions several rules to follow in demonstrating. Rakestraw touches on six different aspects of the


good demonstration in his extensive discussion of lecture-demonstration.

Still others in the "general" group have systematically attempted to list criteria in some form. Billinger lists five requirements for a successful demonstration. Dale offers fourteen suggestions for improving demonstrations and eleven questions for evaluating them. Under "demonstration techniques", Haas lists ten steps to be completed before conducting the experiment and five suggestions for conducting it. Heiss elaborates on seven excellent rules for demonstrating. Holley lists seven things a teacher can do to insure successful demonstrations. Mack developed a lengthy checklist of desirable qualities in demonstration apparatus. In a group thesis edited by Murray, five criteria for a demonstration were listed which had been developed in a seminar.


discussion. Richardson and Cahoon list five criteria for a good demonstration. Selberg lists sixteen common errors in demonstration techniques (actually class experiment techniques) and offers an excellent plan to follow in doing classroom demonstrations. In the second category, the works from the field of biology, only one study was found. Gramet lists eight characteristics of the good demonstration.

In the third category, works from the field of physics, the same breakdown can be made as for the first category. Among the few who emphasize only one aspect, Coyle stresses the value and importance of vertical mounting of apparatus on special boards. Also, Sutton stresses the need for simplicity and originality. Among his suggestions for improving physics teaching, Weaver stresses visibility and size of apparatus.


Hitchcock emphasizes action as the essential quality of good demonstrations and includes, as he elaborates this theme, many other criteria.

Duff is the only one in the field of physics to make a systematic listing. He enumerates nine desirable qualities in demonstration experiments. The fourth and final category, the works from the field of chemistry, may be similarly analyzed. Arthur presented a lengthy discussion on visibility including many excellent suggestions. Reed discusses in some detail four aspects of good demonstrations and techniques. Wiles also deals only with a few aspects of successful demonstrations.

Dunbar lists eleven desirable characteristics in demonstrations. His list is based on Duff's and includes specific examples in chemistry, Frank provides twelve suggestions regarding use of class demonstrations.

1/ Richard C. Hitchcock, "I Like Action in Physics Demonstrations", School Science and Mathematics (December, 1941), 41:832-839.


5/ L. A. Wiles, "The Value of Lecture Table Demonstrations in the Teaching of Chemistry", Journal of Chemical Education (September, 1928), 5:1109-1111.


which he believes to be justified by the experience of a number of teachers. Gould\(^1\) enumerates on eight to consider in planning and performing demonstrations. Van Horne\(^2\) offers five suggestions for the preparation of apparatus and materials and four rules to follow in conducting demonstrations.

**Use of Criteria.**—The seminar in 1951 after careful consideration of criteria of a good demonstration in this field and condensation and telescoping of this material produced the criteria listed below. This group feels it is of no additional value in going on any further with this problem. It is an assumption these are good criteria.

**Selected criteria.**—The criteria for a good demonstration as used in this experiment are as follows:

**CRITERIA FOR A GOOD DEMONSTRATION**

I. **THE DEMONSTRATION SHOULD ILLUSTRATE A BASIC PRINCIPLE.**

II. **THE DEMONSTRATION SHOULD ILLUSTRATE ONE PRINCIPLE ONLY.**

III. **THE ACTION OF THE DEMONSTRATION SHOULD BE CLEARLY VISIBLE AND AUDIBLE TO ALL.**

A. Remove all the audio-visual distractors.

B. Make sure the lighting facilities are adequate.

   Spotlight or otherwise sufficiently illuminate the thing being demonstrated.

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\(^1\) Arthur B. Gould, "Demonstration Experiments and Their Place in the Teaching of Chemistry", *Journal of Chemical Education* (February, 1931), 8:297-302.

C. Adjust window shades so that students can see from all parts of the room.

D. If necessary, rearrange the seating so that everyone has an unobstructed view.

E. Be sure that those with poor hearing and vision are seated appropriately.

F. Have the demonstration table arranged so that all pupils can see the demonstration.
   1) Vertical mounting of apparatus is especially effective.
   2) Place the apparatus well forward on the desk, facing out toward the pupils.
   3) Place demonstration table in best position for all to see from all angles.

G. Wherever possible, make use of color contrast to make the apparatus or materials stand out.

IV. THE APPARATUS SHOULD BE ON A LARGE SCALE.

A. The apparatus must be clearly visible from the furthest corner of the room.

B. Where a thermometer (or other meter) is essential to the demonstration, use a mock-up or working model to help the class visualize this part of the procedure.

C. Large signs and diagrams may be used to supplement the spoken word.
1) They must be previously prepared.
2) They must be clearly visible to all.
3) Green print on yellow is preferable to black on white.

V. THE DEMONSTRATION SHOULD WORK: IT SHOULD BE AS INFALLIBLE AS POSSIBLE.

A. Apparatus should be in sound working condition.

*B. Apparatus should be as simple as possible.
   1) Simplicity of operation.
   2) As few parts as possible.
   3) Avoid crowding, overlapping and masking of the parts.

*C. The demonstration should be rehearsed in advance.

D. The demonstration should be well-planned and prepared.
   1) Set up apparatus and have all materials carefully arranged on the demonstration table before the class meets.
   2) All the necessary measuring and weighing should be done before class.
   3) Scales and graduates should be placed away from the demonstration table when no longer in use.

VI. THE DEMONSTRATION SHOULD BE SIMPLE AND THE SPEED OF ACTION SUITABLE.

A. Use simple setups and place the equipment in

*--These might well be separate criteria.
order on the table so that the action can proceed logically.

B. Talk while you work. Be sure to:
   1) Emphasize the main points; do not digress.
   2) Keep summarizing as you go along.
   3) See to it that the demonstration moves on quickly to a conclusion; do not hurry or drag.

C. Use a simple vocabulary.

VII. THE DEMONSTRATION SHOULD BE DYNAMIC.

A. By definition, movement and action are essential to the demonstration.

B. Positive effects of motion are more impressive than null effects of static display.

VIII. A SLIGHT DRAMATIC ELEMENT IS SOMETIMES USEFUL.

IX. AN ELEMENT OF THE UNEXPECTED IS SOMETIMES EFFECTIVE.

X. THE APPARATUS SHOULD BE OF EASILY AVAILABLE AND INEXPENSIVE MATERIAL.

XI. THE APPARATUS USED IN THE GIVEN DEMONSTRATION SHOULD BE STORED AWAY INTACT UNTIL IT IS TO BE USED AGAIN.

The frequency with which the above-mentioned criteria were mentioned by the sources consulted is indicated by the chart below. The count was made merely for general interest. It has, however, certain obvious values. The frequency of mention of the various criteria provides means of establishing their validity. The table shows the relative importance of the criteria as recognized by these authorities.
information or ability tested by the item"; and "avoid highly technical distractors". In reference to the multiple choice type test, Odell states that "they may be used to test not only knowledge of facts and amount of acquired information, but also knowledge of cause and effect relationships, ability to make comparisons, to evaluate, to apply, to illustrate, to define, and so forth. They are easier to prepare, and also to score, than some of the other types." He further adds "almost all kinds of multiple answer tests can be constructed so that they possess practically perfect objectivity." The scorer is not faced with the problem of partial credit on this type of an examination. Either the response that is checked upon the paper is correct, or it is not correct, with no qualifications.

Levels of difficulty.—The writer is making an attempt to determine to what probable extent application and recognition, as well as understanding of a scientific principle have been gained through the demonstration activity. For this reason, it is necessary for the examiner to approximate the difficulty range of the test items which he has prepared. It is well recognized that there are various levels of learning. In order


2/ Ibid., p. 235


to measure these levels of learning, a testing device of various levels of difficulty must be constructed. The actual judgment of item difficulty must be left up to the subjective judgment of the test constructor. "The use of subjective judgment in estimating item difficulty at the stage of item construction is to be encouraged. Such judgments, when based on all available experience, are distinctly helpful in leading to the construction of items of the desired difficulty."1/ The constructor has ample opportunity to construct the items of various degrees of difficulty by using more remote subject matter applications, or by including usually good distractors in the test items. Odell2/ states that, in reference to good distractors, "their selection will depend to some extent upon how difficult it is desired to make the test. Incorrect answers should, however, never be obviously incorrect to a pupil who knows little or nothing of the matter dealt with."...

The various levels of learning may be broken down to three broad categories. The first level of learning may be labelled, or described as mere factual retention. The second level employs enough understanding of the factual retention so that the learner can recognize and apply, in simple situations, the principles or concepts which he has retained. The third level of learning is reached when the learner can recognize and apply the understanding of the factual material to more complex, unfamiliar, and difficult situations. The test has been constructed with these three levels of learning in mind. The first third of the test is concerned with items of the first level of learning, and so on. Thus,

2/ Ibid., p. 286
the test can be said to measure three levels of learning, all concerned with the same demonstration, and the same scientific principle. This method of testing tells the examiner to approximately what extent the pupil can recall, understand, or apply the principle.

**Vocabulary.**—It is only logical for one to assume that the vocabulary used throughout the experiment must be consistent, or at least on the same level. Vocabulary comprising the test must, of necessity, be equivalent to that used during the demonstration. Inconsistent vocabulary is one of the factors which could unfavorably affect the reliability of the testing program. If the vocabulary within the testing device is inconsistent with that of the oral demonstration, one can expect a low reliability of the whole testing procedure. Reliability, itself, is the consistency with which a test measures "what it measures".

The vocabulary of the testing device has been amended by the critic-jury to establish consistency of vocabulary throughout the experiment and vocabulary comprehension at the grade level at which the test is used.

**The test tryout.**—"After a set of test items has been written, criticized by subject matter experts, and revised on the basis of their criticisms, it must ordinarily be tried out experimentally on a sample of examinees. Prior to any experimentation, the test was subjected to a tryout on at least one hundred pupils of equivalent age and grade level, but are not included in the experiment. This independent tryout tended to expose any unusually poor items, or poor distractors among the possible responses. Such items could be dropped completely from the test, or

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eliminated in the final tabulation of the total results.

As was stated previously, the total number of items in the test approximates thirty, but some may be dropped due to the discretions of the critic-jury, or as a result of the test tryout.

The test period.—The length of the testing period for both the pre-test and the post-test has been indefinite, in so far as no specific time limit has been set for either of the tests. The test period may continue on until every pupil has completed the test, in so far as possible. Each pupil is allotted sufficient time to at least read all of the items presented him. A multiple choice test of thirty items can be approximated as requiring about ten minutes to be read through completely. Odell has recommended that "on the average elementary-school pupils be expected to respond to three or four such exercises multiple choice items per minute."

By allotting sufficient time for all examinees to attempt all the items, the influential factor of time itself is eliminated. As stated by Lindquist "The most common way of reducing or eliminating the influence of time on tests is to set the time limits so liberally that all, or nearly all, pupils are able to consider or attempt all the items in the test." Pupils are told to complete all items, and are watched to see that they keep at this task until finished.


B. Aims and Use of the Test

Employing statistics.--The test is an instrument devised to obtain statistics for measuring growth of learning, due to a specific educational experience, namely a scientific demonstration. Every effort has been made in the construction of the test to measure as precisely as possible, the "meaningful learning" that has been grasped by each pupil subjected to the demonstration and the test-retest procedure. The only descriptions of the learning and understanding that have taken place are the statistics which can be applied to the results of the tests taken by the examinees. In accordance with Guilford, it appears obvious that "statistics enable us to summarize our results in meaningful and convenient form". The summaries of the test results will enable educators in the field of science education to make general conclusions and predictions concerning the presentation of the particular scientific principle that has been demonstrated. Experimental and statistical methods cannot be divorced from each other, in so far as, "The experiment directs our observations and yields data. By means of statistical methods, we can summarize those data, interpret them, and determine their reliability." In this respect, Brownell has stated that "Altogether too commonly understandings are disregarded in evaluation (and in teaching) in favor of outcomes which are more easily measured (and achieved)."


Test-retest method.—If the educator is to measure growth, or learning, due to some specific learning activity, he cannot overemphasize the "importance of knowing initial status with respect to understanding."\textsuperscript{1/}

The writer is convinced that the only reliable method of measuring the amount of learning, due to some specific activity, is by means of the test-retest method. That is, by administering identical tests prior to, and after the learning situation. It is conceded that "not all the gain found can be correctly attributed solely to the remedial program \textsuperscript{2/}the demonstration period\textsuperscript{2/}. Some of it is doubtless due to the practice effect or to familiarity with the test itself, part of it to teaching received outside of school, and part of it to natural growth."\textsuperscript{2/} For purposes of predicting this "probable gain", the writer has made use of a control group in the experiment.

What the test endeavors to determine.—Any increase in scores of the control group on the post-test (the same test that has been given the second time) may be labelled as the probable gain that can be attributed to familiarity, or external factors concerning the test. The writer has sought to determine the significant increase of the scores on the post-test of the experimental group, and compare this increase with any possible increase made by the control group on the post-test. By knowing approximately what percentage gain on the test scores may be attributed to "chance", as determined by the control group, the writer is able to conclude in this instance, that any significantly larger gain in

the scores of the experiment group has been due to learning gained during the demonstration process.

Assuming that the constructed test is both reliable and valid, statistics applied to the results emanating from the test will yield invaluable data in predicting at what grade, or grades this specific scientific principle can be presented with predictively good results. Statistical interpretations of the test results are the means to these predictions. This is stated in essence by Guilford who states that "statistical reasoning is basic to all predictions".

C. Characteristics of the Test

Reliability of the test. — The reliability, being the precision and consistency with which the test measures "what it measures", is a most important characteristic of the test. In this specific testing situation, the scores on the pre-tests and post-tests given to the experimental group cannot be correlated for purposes of determining reliability since the material being tested has been presented to the examinees in the period intervening the two tests.

All external factors concerning the test have been kept as consistent as possible. The element of time does not detract from the reliability, because provisions have been made for each pupil to at least consider all

1/ Ibid., p. 176
the test items. The influential time factor has been kept at a minimum. Lindquist\(^1\) concurs in stating that "The procedures \(\text{Testing}\) become entirely unsatisfactory particularly in any test in which speed is a significant element in the score".

The sampling of the material has been adequate, since all the test items have been constructed on the basis of a single scientific demonstration. A test of high reliability is further assured in the length of the test. It is generally conceived that the longer the test, the higher the reliability. The test in consideration contains approximately thirty items, measuring the understanding derived from a single scientific principle.

**Validity.**—Validation of the test items has been by jury, as mentioned previously. The jury was composed of in-service science teachers.

\(^1\) E. F. Lindquist (Editor), Educational Measurement, *op.cit.*, p.617.
CHAPTER III
EXPERIMENTAL PROCEDURE

1. Preparation and Operation
of the Demonstration

Scope of the thesis.-- The procedure of this study will try to discover the grade placement of the principle, "The amount of momentum possessed by an object depends upon its weight and speed of motion," at the fourth and sixth grade level, and with considerations of mental ages. In the experimental procedure, as mentioned above, the lecture-demonstration type of instruction was used. The demonstration was designed specifically to illustrate the one basic principle of momentum.

Construction of the demonstration.-- Since two factors, speed and weight, are involved in the principle, the demonstration was constructed with two main pieces of apparatus. One is the Momentum Meter, designed to measure the relative momentum of rolling pool balls. The second is merely an inclined plane designed to show that added weight results in additional momentum.

Operation of the apparatus.-- The Momentum Meter is built with a detachable runway about 2\frac{1}{2} feet long. This
can be adjusted at several angles to vary the speed of the rolling pool balls. As the balls are rolled, they come in contact with a projecting piece of wood at the bottom. This wood is set up with an elastic, so that it is pushed further as the momentum of the rolling balls is increased. The force on the piece of wood turns a gear which registers on a clock-like meter in front. Thus, the demonstration clearly shows that increased momentum will register a relatively higher number on the meter.

The inclined plane is a runway about 3½ feet long and fixed at an angle of about 35 degrees. Nearly at the base, a piece of ordinary window glass can be placed broadside to the slope of the runway. A simple four-wheeled vehicle is rolled down, at first empty, so that it hits the glass head-on. The glass does not break. A brick is then tied to the vehicle, increasing the weight manifold. When it is rolled against the glass again, the glass smashes. It shows that increased weight means more momentum, assuming that the speed is constant.

Initial demonstration.-- These devices were at first shown to a group of science teachers for criticism. Several worth-while suggestions were given, and changes were made in the demonstration. In addition, the writer made a trial run before three combined classes not otherwise used in the study. Free comment, criticism, and questions were
invited. Changes were made as before so that the demo- 
cration would be as clear, as simple, and as understandable as possible.

2. Preparation of the Test

\textbf{Obtaining statistics.}-- In order to obtain statistics for measuring the growth of learning, a test was devised. The items contained were designed to measure the learning growth of the single science principle and its applications.

\textbf{Selecting the items.}-- Items were constructed to test three levels of difficulty. About nine, or one third of the items, were based directly on the demonstration; one third demanded a certain amount of transfer from the demonstration; and the last third required much transfer and knowledge gained from the demonstration. Twenty-eight multiple-choice items were made, each with a correct answer and three distractors. Each item was recorded on a single card and submitted to a group of science teachers for criticism.

\textbf{Preparing the test as a unit.}-- The writer then made changes, prepared the test as a unit, and submitted it to a group of three classes not otherwise used in this study. After this criticism, the writer included in his test 26 items that he felt conformed to the characteristics of good items.

A copy of the test appears in the Appendix.
3. Schools Visited

Population used.-- The population used in this study was composed of 254 pupils from the fourth and sixth grades of five schools. The city concerned is industrial, on the North Shore of Massachusetts, and has a population of 25,000. It has a large shoe-machinery factory, smaller electronics and leather plants, and is a shopping center for several surrounding communities. It represents an average small coastal city of New England, the inhabitants being largely of the lower-middle socio-economic level.

A large high school, a junior high, a trade school, and nine elementary schools make up the public school system. The five schools used in this study are located in the city outskirts. They contain, therefore, students of a higher socio-economic background than do the downtown schools.

4. Administration of the Pre-test

Test-retest method.-- A test-retest method of measuring growth was decided upon. Each pupil was given two science tests, the first called the pre-test and the latter called the post-test. These were identical except that the items in the second test were scrambled.

Arranging to give the test.-- The writer approached the city superintendent of schools and explained the purpose and the nature of the research project. The superintendent
appeared interested and arranged for interviews between the writer and the principals of five schools which he chose.

A definite date and time for the demonstration was cleared with each principal in advance. The principal agreed to have one fourth grade ready in one classroom and one sixth grade ready in another. The writer entered the fourth grade classroom first.

Explaining the pre-test.-- A text of introduction and explanation, prepared in advance to ensure similarity of instruction, was given. A copy of this appears in the Appendix. After giving the instructions, the writer passed out the pre-tests which were specially marked. He then went to the sixth grade classroom and proceeded to administer the pre-test as before.

Dividing the classes.-- After a reasonable length of time had elapsed, so that everyone at least had a chance to read all the items, the two classes were divided. This was done by means of the random numbers which appeared in the corner of each test. Half of the sixth grade combined with half of the fourth grade and took seats in the fourth grade room. This was known as the experimental group, or the ones who would see the demonstration before doing the post-test. The other combined fourth and sixth graders were known as the control group. They took seats in the sixth grade classroom and were allowed to read non-science material
while the demonstration was going on.

_Giving the demonstration._— The writer then set up the demonstration before the experimental group. A prepared script was used to ensure similarity of instruction. A copy of this will be found in the Appendix.

_Giving the post-test._— After the demonstration was given, the writer administered the post-test, specially marked, to each group simultaneously. A reasonable length of time was again allowed, and the tests were collected. A science demonstration was at this time given to the control group so that it would not feel as though it were cheated.

_Otis Mental Tests._— In order to obtain the mental age of each pupil, the Otis Quick-Scoring Tests of Mental Ability, Form Beta A, were given. The writer left these with the teacher and asked that they be given within two weeks.

5. Handling of the Statistics

_Scoring the tests._— The writer then scored each science test and each Otis Test. Each student's tests were marked and clipped together so that the information on them could be easily recorded.

_Pupil record cards._— The following information was then recorded on special pupil record cards: (1) the name

1/Arthur S. Otis, _Otis Quick-Scoring Mental Ability Tests_, World Book Company, Yonkers-on-Hudson, 1928
of the child; (2) birth date; (3) chronological age; (4) mental age; (5) school; (6) grade; (7) teacher; (8) Otis Test score; (9) sex; (10) experimental or control group; and (11) the scores of the pre-test and the post-test. A column on one side also indicated whether or not the pupil's response to each item was correct. This helped greatly on the item analysis later on.

Marking the items.-- Marking each item on the pupil record card was done in this way. If the pupil got the first item right on the pre-test, the writer put a red line beside a box, numbered as the item, on the card. A blue mark indicated that the pupil answered correctly on the post-test. No mark indicated two misses, while a red and a blue mark showed that the pupil got the item right on both the pre-test and the post-test.

Making the performance chart.-- The writer then made a chart showing the performances of the different mental age groups on the science post-test. This was done separately for the experimental and the control groups. The median and the inter-quartile range for each mental age group, set up in intervals of 12 months, are shown on Table 2.

Eliminating the deviates.-- The writer then proceeded to eliminate the deviate scores from the mean Otis score. This was done so that a typical sampling would remain, in
the middle 80 per cent.

The means and standard deviations of the Otis Tests were computed for both classes in the five schools. Multiplying the standard deviation times 1.28 yielded a number. This number plus or minus the mean gave the limits of the middle 80 per cent. Any card with a number beyond the limits was taken out and not used further in the study.

The pupil record cards were then sorted by grade, ranging from the high Otis score on the top to the low Otis score on the bottom. Due to chance massing of the Otis scores at the upper or lower limits, each grade group was checked to see that the middle 80 per cent exactly was retained.

Finding the upper and lower 27 per cent. -- The writer then separated the cards of each classroom into experimental and control groups. The control-group cards were laid aside for a little while. The cards of the experimental group of each grade were assorted ranging from the high Otis score on top to the low on the bottom. Twenty-seven per cent of the number of cards were taken from the top and the same number from the bottom. Then, the cards were pooled and assorted into four groups: (1) fourth grade upper; (2) fourth grade lower; (3) sixth grade upper; and (4) sixth grade lower.

Doing an item analysis. -- Using the four packs, the writer then did an item analysis on the science test to plot
the difference of performance on a given item from group to group. Four worksheets were made, each containing 26 axes or crosses divided into four quadrants. Each axis stood for an item, and each worksheet stood for a group of 27 percent.

Making the quadrants.-- Two cards of one group had red marks after the box representing item one. The number two was placed in the upper left quadrant of the axis corresponding to the item. If four cards of the group had red and blue marks, the number four was put in the upper right quadrant. If seven cards had blue marks, the number seven was put in the lower right quadrant. A zero in the lower left quadrant indicated that there were no blank boxes after the item.

Changing the numbers to proportions.-- In each axis, the sum of those scoring correctly on the pre-test was changed to a proportion. Adding the numbers in the top quadrants and dividing the sum by the total number of responses accomplished this. The same was done on the post-test. The sum of the numbers in the two right quadrants gave the total of correct post-test responses.

Correction for guessing.-- The statistics would not be accurate unless a correction for guessing were allowed. Each proportion, then, was referred to a chart, and the

\[1\]

corrected number was recorded.

Finding the difficulty index.-- What percentage of a hundred pupils in each grade would get an item right is known as the difficulty index. For each item and for each grade, the difficulty index was recorded by use of the 1/Davis chart. The performance of the lower 27 per cent was thereby compared to the performance of the upper 27 per cent in each grade. A discriminating index was also recorded, but not used at this time.

Eliminating the items.-- The writer then eliminated the poor items, using the following criteria. The item was eliminated (1) when the difficulty index for the item indicated no gain or decrease from the lower grade pre-test to the higher grade pre-test; (2) when it was too easy, or when 75 per cent of the pupils in the lower grade got the item right; (3) when it was too difficult, or when 25 per cent of the pupils in the higher grade failed to get the item right on the post-test; (4) when the difficulty index indicated no gain from the pre-test to the post-test at both grade levels on any item; and (5) when the difficulty index showed a gain at the lower grade and a loss at the upper grade from the pre-test to the post-test.

The elimination of 15 items was necessary, leaving 11 of the original 26. The items which were retained are

preceded by an asterisk (*) in the test in the Appendix.

Computing the means and standard deviations.-- The writer then computed the means and standard deviations of the pre-tests and the post-tests of each grade control group and each grade experimental group. The revised test of 11 items was used. Tables 3, 4, and 5 show these means and standard deviations.

Finding the reliability.-- In order to find out whether or not the test functioned consistently, the reliability was computed. Only the control group was used. The formula used Pearson's Product-Moment Coefficient of Correlation: 1/

\[
    r_{tt} = \frac{\sum_{XY} - C_x C_y}{\sigma_x \sigma_y}
\]

- \(r_{tt}\) = the coefficient of correlation
- \(N\) = the number of cases
- \(\sigma_x\) = the standard deviation of the distribution on the "x" axis
- \(\sigma_y\) = the standard deviation of the distribution on the "y" axis
- \(c_x\) = the correction on the "x" axis
- \(c_y\) = the correction on the "y" axis
- \(\sum_{XY}\) = the sum of the products of the deviations of each measure from the central tendency of the "x" axis and the "y" axis

The method of finding the reliability was by means of correlating scores on the pre-test and those of the post-test on a double-entry table. Each tabulation stood for the result of the pre-test and the post-test performance of an individual.

The reliability of the test at grade six tended to be high, since the tabulations on the table clustered upward and to the right. A reliability of 0.89 was found at the sixth grade, and a reliability of 0.73 was found at the fourth grade.

Proportion passing.-- In order to find the proportion passing the pre-test and the post-test at each grade level for both groups, a mastery level had to be found. If a pupil scored above the mastery level, he was said to know the principle and its applications well.

Since a certain error is apt to occur in any test, the standard error of the obtained measure ($\sigma_t$) was found for each group from the formula:

$$\sigma_t = \sigma \sqrt{1-r}$$

$\sigma$ = the standard deviation

$r$ = the reliability as found by the Pearson coefficient of correlation

The standard error of the obtained measure was then multiplied by 2.58, which is the one per cent level of significance. This product subtracted from the number of items gave a point beyond which mastery was said to occur. By dividing the number of cases in each group into the number of cases who mastered the test, a decimal was yielded. This was changed to a percentage which represented the proportion passing. Tables 4 and 5 show these computations.
Table 2. Performance of Different Mental Age Groups on Test of Momentum for the Total Population

<table>
<thead>
<tr>
<th>Mental Age Ranges</th>
<th>Experimental Group</th>
<th></th>
<th>Control Group</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Median Score</td>
<td>iqr</td>
<td>Number</td>
</tr>
<tr>
<td>17-18...</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>16-17...</td>
<td>7</td>
<td>23</td>
<td>22-24</td>
<td>4</td>
</tr>
<tr>
<td>15-16...</td>
<td>7</td>
<td>24</td>
<td>23-25</td>
<td>11</td>
</tr>
<tr>
<td>14-15...</td>
<td>9</td>
<td>24</td>
<td>22-25</td>
<td>12</td>
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<td>13-14...</td>
<td>14</td>
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<td>22-23</td>
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<td>17-23</td>
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<td>17-22</td>
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<td>17-23</td>
<td>21</td>
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<td>14-19</td>
<td>12</td>
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<tr>
<td>8-9...</td>
<td>3</td>
<td>14</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>Total...</td>
<td>119</td>
<td></td>
<td></td>
<td>135</td>
</tr>
</tbody>
</table>

Number means "number of testees"

iqr means "inter-quartile range"

The appearance of a dash (-) means that there were not enough cases to make a computation.
Table 3. Means and Standard Deviations of the Pre-test for the Fourth and Sixth Grade Experimental and Control Groups

<table>
<thead>
<tr>
<th>Grade</th>
<th>Pre-test Control</th>
<th></th>
<th>Pre-test Experimental</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
<td>Mean</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>Fourth Grade</td>
<td>5.57</td>
<td>2.28</td>
<td>5.77</td>
<td>2.40</td>
</tr>
<tr>
<td>Sixth Grade</td>
<td>6.92</td>
<td>2.08</td>
<td>6.63</td>
<td>2.51</td>
</tr>
</tbody>
</table>

Table 4. Means, Standard Deviations, and Proportion Passing on the Pre-test and the Post-test for the Fourth and Sixth Grade Control Groups

<table>
<thead>
<tr>
<th>Grade</th>
<th>Pre-test</th>
<th></th>
<th>Post-test</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
<td>Proportion Passing</td>
<td>Mean</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>Fourth</td>
<td>5.57</td>
<td>2.28</td>
<td>17</td>
<td>5.47</td>
</tr>
<tr>
<td>Sixth</td>
<td>6.92</td>
<td>2.08</td>
<td>25</td>
<td>6.73</td>
</tr>
</tbody>
</table>
Table 5. Means, Standard Deviations, and Proportion Passing on the Pre-test and the Post-test for the Fourth and Sixth Grade Experimental Groups

<table>
<thead>
<tr>
<th>Grade</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Sixth</td>
<td>6.63</td>
<td>2.51</td>
</tr>
<tr>
<td>Fourth</td>
<td>5.77</td>
<td>2.40</td>
</tr>
</tbody>
</table>
CHAPTER IV
ANALYZING THE TABLES

Table 2 shows the performance of different mental age groups on the test of momentum. It indicates, but not conclusively, that the higher a mental age a pupil has, the better are his chances of scoring high on the test on momentum. The range of median scores of the control group for the various age ranges is not as uniform as that of the experimental group. For instance, the median for the 12-13 year mental age group is 18. The median for the higher mental age group of 14-15 is a lower score of 16. The range of scores of the experimental group is such that the low science scores start with the low mental age group and go uniformly higher as the mental ages increase.

In the 11-12 mental age group, the gain in the median score from the control group to the experimental group was two points. In the 10-11 mental age group, the gain was five points. In the 9-10 mental age group, the gain was two points. Of these groups, the greatest growth in learning took place in the 10-11 mental age group.

Table 3 shows that there is no significant difference in the performance in the pre-test by the experimental and control groups. The experimental group in the fourth grade
performed slightly better on the momentum test than the control group, and the control group in the sixth grade performed slightly better than the experimental.

Table 4 shows that there is almost no change in the performance of the control groups from pre-test to post-test. In fact, the only change at all was that the fourth grade did infinitesimally worse from pre-test to post-test.

Table 5 shows that there is great gain from the pre-test to the post-test at each grade in the experimental groups. The greater improvement of performance from the pre-test to the post-test appeared at the sixth grade. Twenty-three per cent of the sixth grade experimental group passed the pre-test, whereas sixty-three per cent passed the post-test. This shows a better, but not significant, gain than the fourth grade which went from 27 per cent on the pre-test to 60 per cent in the post-test.

A comparison of Table 4 and Table 5 indicates a gain in the performance of the post-test by the experimental group over the performance of the post-test by the control group.
CHAPTER V

CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

It is now possible to make conclusions about the grade placement and the mental age placement of the principle, "The amount of momentum possessed by an object depends upon its weight and speed of motion."

A growth in learning of this principle occurred with those who saw the demonstration before doing the post-test. Those who did not see the demonstration performed almost identically on both tests.

The test items were more difficult for the fourth grade pupils than they were for the sixth grade pupils.

The test functions more consistently at the sixth grade level than it does at the fourth, due to a higher reliability at the sixth grade.

A greater, but not significant, amount of learning took place in the sixth grade.

A significant growth of learning exists from the control group to the experimental group at the mental age level which could well represent the sixth grade.

Therefore, the principle, "The amount of momentum possessed by an object depends upon its weight and speed of
motion," should be taught at the sixth grade level rather than at the fourth grade level. Sufficient evidence does not exist to justify pin-pointing the principle at grade six.

The writer, therefore, suggests that this principle be tried at the fifth grade. The difference in the growth of learning between the fourth grade and the sixth grade is not great. It may be greater at the fifth grade.

Since between 17 and 25 per cent of all pupils scored better than the mastery level, the writer suggests trying the principle at grade three. At this time it could be discovered whether or not the learning growth was significant.
APPENDIX
1. Two snowballs of the same size start rolling down a hill. The first gathers snow as it rolls, but snow will not stick to the second. The first will have more momentum because
   a. there is nothing to stop it.
   b. it is heavier.
   c. it slides over the snow better.
   d. it rolls down in a curve.

2. A bowling ball will knock over more pins than a golf ball rolled at the same speed because
   a. it is harder.
   b. it rolls better.
   c. you can grip it better.
   d. it weighs more.

3. A man wants to knock over a large pole with a bulldozer. He should get a good head start because
   a. the start will give him more momentum.
   b. the momentum will keep the pole from breaking.
   c. no one knocks over poles standing still.
   d. it will not damage the blade that way.

4. A blue car is going 60 miles an hour and crashes into a fence. A red car hits the same fence but does not go through. Why?
   a. The brakes are better.
   b. It is only going 20 miles per hour.
   c. The first car skidded.
   d. It is a better made car.

5. A train which has brakes only in the locomotive can't stop easily because
   a. trains don't have as good brakes as cars.
   b. the cars behind push the locomotive forward.
   c. the cars slide easily.
   d. the tracks are smooth.

6. Race horses don't stop exactly on the finish line at the end of a race because
   a. they can win whether they stop short or not.
   b. they have been going very fast.
   c. they are heavy.
   d. their legs aren't strong enough.

7. Which of these will have more momentum?
   a. A bullet that is thrown?
   b. A bullet that is dropped?
   c. A bullet that is fired from a gun?
   d. A bullet that is hit with a baseball bat?
8. Bill and Dick weigh the same. They go down two slippery slides which are alike. Dick gets a push, but Bill doesn't. Dick will have more momentum because
   a. no two boys weigh exactly alike.
   b. the wind does not hold him back.
   c. he knows how to lean.
   d. his speed is greater.

9. Two 1953 Fords are riding side by side. The first is going 50 miles per hour, and the second is going 25. Both have to stop suddenly. Which is right?
   a. The momentum is the same in both cars.
   b. Both will stop at the same time.
   c. The second car will stop sooner.
   d. The first car will stop sooner.

10. Some firemen who went to crash through a heavy door can't do it. It would help if they
    a. get a good head start.
    b. don't go as fast.
    c. go through a window.
    d. pushed near the doorknob.

11. Which one of these rolling down a coal chute would have more momentum?
    a. A pool ball?
    b. A tennis ball?
    c. A ping pong ball?
    d. A golf ball?

12. Bob coasts down a hill in his cart. Then Sally coasts down in the same path. Bob goes much farther because
    a. he knows how to steer better.
    b. boys can coast better than girls.
    c. he weighs much less.
    d. he weighs much more.

13. Two cars, just alike, are going thirty miles per hour. The red one has five people in it, but the green one has just the driver. The momentum of the red car is
    a. less because the extra weight holds it back.
    b. holding it back.
    c. more because it has more weight.
    d. the same as the other.

14. A man rolls a bicycle wheel and then an automobile wheel down a hill. The bicycle wheel hit a fence, but did not go through. What could have happened to the automobile wheel?
    a. That couldn't have followed the same path.
    b. It hit the bicycle wheel and stopped short.
    c. It couldn't have gone through either.
    d. It crashed through.
15. When it sets rolling, a train that is loaded will be harder to stop than a train with empty cars because
   a. it is faster than the empty train.
   b. empty trains don't have to have as good brakes as full ones.
   c. it is heavier than the empty train.
   d. the brakes will be harder to put on.

16. Jack is rolling a hoop with a stick. In order to give the hoop more momentum, he should
   a. make it go faster.
   b. roll it over another ground.
   c. oil it.
   d. change sticks.

*17. A man was driving fence posts into the ground. He used a mallet, but they would not go in well. Which one of those would help?
   a. He should swing the mallet faster.
   b. He should get a lighter mallet.
   c. He should get a new handle for the mallet.
   d. He should quit and try the next day.

18. A huge iceberg hit a large ship at sea. The ship sank. The momentum of the iceberg was greater because
   a. the iceberg hit the ship sideways.
   b. the ship was not going full speed.
   c. the iceberg weighed much more than the ship.
   d. ice weighs more than steel.

*19. A loaded truck starts rolling downhill with no one in it. If it had been empty instead of loaded
   a. it would have had more momentum.
   b. you couldn't say for sure about the momentum.
   c. the momentum would be the same in both cases.
   d. it would have had less momentum.

20. Two 1951 Plymouth cars are going along side by side. The first is going 30 miles per hour and the second is doing 60. Both have to stop suddenly. Which of these facts is true?
   a. They both will go the same distance.
   b. The second car will go further.
   c. You can't say for sure about the stopping.
   d. The first will go further in stopping.

21. A man who weighs 125 pounds jumps on the ice on a pond. He did not go through. Another man jumped on it and went through. He must have
   a. weighed less.
   b. weighed more.
   c. not measured the thickness of the ice.
   d. forgotten about safety rules.
*22. Jack and Mike are trying to knock marbles out of a circle by flipping one marble against another. Mike would do better if he
   a. flipped a heavier marble.
   b. quit while he could.
   c. changed to a lighter marble.
   d. made the circle larger.

*23. A man is letting grain bags slide down a chute, but they stop half way down. It would help if he
   a. made the angle of the chute steeper by putting the high end up.
   b. took the grain out of the bags.
   c. used lighter bags.
   d. let the high end of the chute down.

24. Ed who weighs 120 pounds tries to break through a door with his body but cannot. Sam who weighs only 100 does break through. He must have
   a. had a harder head.
   b. hit the door head first.
   c. known about doors.
   d. hit the door with more speed.

25. Some boys were throwing rocks which would not break through the ice on a pond. George finally threw one that broke through. He must have
   a. thrown five rocks at once.
   b. used a heavier rock.
   c. made the rock spin.
   d. gotten a rock with a sharp point.

*26. One car going thirty miles an hour hits a wall but does not go through. Another car going twenty miles per hour hits the same wall, knocks it down and goes through. The driver of the second car must have
   a. had a harder bumper.
   b. not seen the wall.
   c. had a heavier car.
   d. had a better car.
Name ___________________________ Age _______ Grade ______
School ________________________ Boy _______ Girl _______ Number ______

Directions: After each question on the test page, you will see four answers listed. Each answer has a letter in front of it, either a, b, c, or d. Pick out the best answer and put the letter that goes with that answer after the number on the answer sheet. For instance, if you think that the right answer for the first question is b, you will mark b after number 1 on the answer sheet, like this:

1. b

Answer all the questions.

1. _______ 14. _______
2. _______ 15. _______
3. _______ 16. _______
4. _______ 17. _______
5. _______ 18. _______
6. _______ 19. _______
7. _______ 20. _______
8. _______ 21. _______
9. _______ 22. _______
10. _______ 23. _______
11. _______ 24. _______
12. _______ 25. _______
13. _______ 26. _______
"You are now going to help Mr. Perkins and a group of men and women working with Professor Read at Boston University. They want to know just how much you children, and many other children like you, know about a certain part of science. You will all take a test. It will not count toward your marks. Relax and feel as though you are helping because, without you, this thing would be impossible. All the questions are about a part of science called momentum. I don't think that there is anyone here who knows exactly what the word means, and I'm not going to tell you now. Perhaps from reading some of the questions you will get an idea.

"If there is any other word in the test that you don't know, raise your hand and the teacher will explain it. You now have a test booklet and an answer sheet. Do not put any marks in the test booklet. On the answer sheet, fill in your name, your age, your grade, and your school. If you are a boy, put an "X" after boy; if you are a girl, put an "X" after girl.

"Now let's look at the directions on the answer sheet. Read them to yourselves as I read them aloud. Are there any questions? This is not a speed test. When you are through, put your pencil down and wait."
I am now going to show you something about momentum. I will ask you not to ask any questions during the demonstration.

We will think of momentum as the forward movement that a thing has, and the power to keep it moving. Anything that moves has momentum. Some moving things have more momentum than others.

Now I will tell you something about momentum. Read to yourselves what is on this card while I read it aloud. "How much momentum something has depends upon its weight." That means that if this tennis ball were rolled at the same speed as this pool ball, which is much heavier, the pool ball would have more momentum, or power to go forward.

Let me tell you something else about momentum. Again, you read this card silently while I read it aloud. "How much momentum something has depends upon its speed of motion." That means that if I roll this orange pool ball and it goes fast, and I roll this black pool ball and it goes slowly, the orange pool ball will have more momentum.

Now let's see what we've learned so far. Read this card silently as I read it aloud. "How much momentum something has depends upon its weight and speed of motion."

Now, let's look at this. It's called a momentum meter. You probably know that a meter is something that measures.
We are going to see how much momentum certain things have by watching the arrow. Something that has much momentum will make the arrow go further around than something that doesn't have much momentum.

Let's first take a rubber ball and roll it down the board. It barely makes the arrow move because it is so light. It does not have much momentum. This pool ball will be rolled at nearly the same speed, but it is heavier than the rubber ball. Notice that it makes the arrow go around to a higher number. It has more momentum than the rubber ball.

Now I will make the speed of the pool ball more by raising the angle of the board. Notice that it makes the arrow go around even further than the last time. That is because I made the speed greater. Thus, the faster a thing rolls, the more momentum it has.

If the arrow goes around to the red line, a buzzer will ring. Let's see if we can make the momentum enough to make the arrow cross the line. Remember, to make the momentum more, we make the weight more or the speed more or both. We will add a pool ball and roll them. This makes the weight much more, but there is still not enough momentum to make the buzzer ring. In order to make the momentum more, we will make the speed more. This we will do by raising the angle of the board. You see now that there is enough extra
weight and extra speed to make the momentum greater.

Here is something else to show you that the heavier a thing is, the more momentum it will have when moving. I will put this piece of glass in the slot in the runway. I will now make this little cart run into it from the starting line. Notice that it is light and does not have enough momentum to crash through the glass.

I will now tie this brick to the cart and make it much heavier. I will roll it at about the same speed. Let's see what happens. The extra weight has given the cart much more momentum and kept it moving—right through the glass.

Now do you see that how much momentum a thing has depends upon its weight and speed of motion? You will now take the same test over again to see if you can make a better score.
The facets of the demonstration of momentum are as follows: (1) a Momentum Meter; (2) a runway; (3) two pool balls; (4) a tennis ball; (5) two signs with the principle written on them; (6) a small vehicle; (7) a brick.
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