1959

The construction and use of a test of physical science as it is offered in the State Teachers Colleges of Massachusetts.

BOSTON UNIVERSITY

SCHOOL OF EDUCATION

Dissertation

THE CONSTRUCTION AND USE OF A TEST OF PHYSICAL SCIENCE AS IT IS OFFERED IN THE STATE TEACHERS COLLEGES OF MASSACHUSETTS

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(Ed. M., Boston College, 1937)

In Partial Fulfillment of Requirements for

the Degree of Doctor of Education

1959

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CHAPTER I

THE PROBLEM

The major purpose of this study was to prepare an achievement test which would adequately measure mastery of the content of a course in physical science required for all elementary education majors in the Massachusetts State Teachers Colleges.[1/] The results obtained from the administering of this test were used to indicate areas of strength, weakness, and growth in the mastery of subject matter.

Scope of the study.-- Although there are nine State Teachers Colleges offering majors in elementary education, at the time this test was administered only eight of the colleges were giving the course in physical science. The test was presented to all available elementary majors.

The basis of the hypothesis of this testing is that without a core of basic factual knowledge, it is impossible to attain some of the broader outcomes outlined for the science course. Hence, the testing is limited to measurement of knowledge of facts, concepts and principles.

Justification for the study.-- All prospective elementary school teachers in the colleges are required to take this

1/Department of Education, Commonwealth of Massachusetts, Report of the Committee to Study General Education in the Massachusetts State Teachers Colleges, Boston, 1959, pp. 96-97.

course. The science faculties of the colleges have agreed upon an outline for the course. However, the outline offers few suggestions for implementation or for the relative amount of emphasis to be placed on each of the several suggested topics. Moreover, no one knows whether the average student in this course is capable of mastering many of the concepts presented. This student may have had science courses in secondary school and he has successfully completed a course in general biology at the college level. Yet it is generally believed by those who teach the physical science courses that the average student enters these courses with a poor background knowledge of physical science.

The test was given at the beginning and at the end of the first academic year in which the outline was used by all the colleges. The analysis of the pre-test showed general areas of weakness. The analysis of the post-test showed relative amounts of growth and indicated to the instructors concerned that some of the areas in the outline should be modified for this college population.

This is the second study which concerns the General Education program of the Massachusetts State Teachers Colleges. A recent one was completed by Julian Roberts [1/] in the field of English.

1/Julian Roberts, The Teaching of English Literature in General Education: An Experimental Comparison of Two Methods of Instruction, Unpublished Doctoral Dissertation, Graduate School of Education, Harvard University, Cambridge, Massachusetts, 1957.

It is hoped that ultimately, as a result of this and future testing, the physical science course of study at the Massachusetts State Teachers Colleges can be revised and that the revision will be on the basis of available factual data.

CHAPTER II

REVIEW OF RELATED RESEARCH

Trend in testing of science learning.-- The trend in the evaluation of science instruction over the past quarter of a century has been toward the measurement of such outcomes of instruction as: scientific thinking, reasoning, scientific attitude, application of laws and principles, and the relating of scientific knowledge to the every day environment.

The Educational Testing Service has made available a *Test of Science Reasoning and Understanding*[1/] which attempts to measure such outcomes through questions on an understanding of the reading of scientific articles at different levels.

Dressel and Mayhew[2/] describe a similar type of test which at one college was used with both the biological and physical science courses over the same year period. Both groups made significant gains on both tests, but the gain made in each course on the test related to that area was significantly higher than that in the other course. The indication is clearly that achievement of the objectives of science

1/Educational Testing Service, *Test of Science Reasoning and Understanding: Physical Sciences, Form A*, Princeton, New Jersey, 1955.

2/Paul L. Dressel and Lewis B. Mayhew, *General Education: Explorations in Evaluation*, American Council on Education, Washington, D. C., 1954, pp. 132-133.

reasoning and understanding involve both knowledge and familiarity with the material and ability to reason in it.

Burmester 1/ describes the construction of a test to measure some of the inductive aspects of scientific thinking. The test consists of a number of paragraphs with multiple selections for interpretation. It appears to be rather an unwieldy instrument and is based on a course of study in biology. Her test is divided into sub-tests which claim to measure: steps in scientific thinking, delimitation of problems, experimental procedures, organization of data, evaluation of hypotheses, experimentation and the interpretation of data, drawing of conclusions, and generalizations and assumptions. The test is validated by correlation with measures of intelligence, reading ability, and factual information.

Dunning 2/ describes "The Construction and Validation of a Test to Measure Certain Aspects of Scientific Thinking in the Area of First Year College Physics." However, he limits his test to certain specific areas, namely, the interpretation of data and the ability to apply principles. He suggests that his test can be used in general education physical science courses.

1/Mary Alice Burmester, "The Construction and Validation of a Test to Measure Some of the Aspects of Scientific Thinking," Science Education (March, 1953), 37:131-140.

2/Gordon M. Dunning, "The Construction and Validation of a Test to Measure Certain Aspects of Scientific Thinking in the Area of First Year College Physics," Science Education (April, 1949), 33:221-235.

Edwards [1/] concluded that the test instrument he constructed to measure critical thinking in science was unsatisfactory. Careful study of his report leads to the additional conclusion that there will be no critical thinking ability to measure unless it is taught.

In an earlier article Noll [2/] describes methods of measuring scientific attitude. The problem at that time was no different than it is today. Attitude is difficult to define to the satisfaction of many and, by many definitions, any measure of it will not be reliable.

Read [3/] states that in general, questions on scientific attitude can be made valid, but that they are somewhat difficult to establish.

Burke [4/] also concludes that the construction of items to measure the so-called "higher" levels of science learning is most difficult.

Many similar examples of research in the measurement and evaluation of higher thought processes and attitudes could be cited.

1/T. Bently Edwards, "Measurement of Some Aspects of Critical Thinking," Journal of Experimental Education (March, 1950), 18:260-278.

2/Victor H. Noll, "Measuring the Scientific Attitude," Journal of Abnormal and Social Psychology (July-September, 1935), 30:145-154.

3/John G. Read, "Construction and Evaluation of a New General Science Test," Science Education (December, 1951), 35:264.

4/Paul J. Burke, "Test of Critical Thinking in Physics," American Journal of Physics (December, 1949), 18:530.

Objectives of instruction.-- A reference containing a classification of objectives in the cognitive domain has been prepared by Bloom [1/] and others. Their handbook contains major categories with illustrative objectives and test items.

Any attempt at evaluation must begin with a consideration of the objectives of instruction. The Forty-sixth Yearbook of the National Society for the Study of Education [2/] lists the following as desirable outcomes of science instruction: "functional information, functional concepts, functional understanding of principles, instrumental skills, attitudes, appreciations, and interests."

However, Hook [3/] comments on our willingness to formulate objectives and to overlook the difficulty of implementing them. Long lists of the objectives of science are frequently prepared and, as in the present study which deals with 22 instructors of physical science in eight colleges, it is difficult to reach any agreement.

One common objective on which all can agree is stated in the course of study in physical science prepared by the Committee to Study General Education in the Massachusetts State

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1/B. S. Bloom, et al., Taxonomy of Educational Objectives, Handbook 1: Cognitive Domain, Longmans, Green and Co., New York, 1956.

2/National Society for the Study of Education, Science Education in American Schools, Forty-sixth Yearbook, 1947, Part I, University of Chicago Press, Chicago, p. 251.

3/Sidney Hook, "Perennial and Temporary Goals in Education," Journal of Higher Education (January, 1952), 23:2.

Teachers Colleges.[1/] This objective is stated: "to develop an understanding of the fundamental concepts of the physical sciences." The committee goes on to say that the course in physical science "should lay the foundations for understanding of scientific concepts." It recommends "a course in physical science built around a core of physics" and that the topics on meteorology, climatology, and earth science usually found in courses of this type be placed in the course offerings in geography.

Dressel and Nelson[2/] give the following as a condensation of Bloom's Taxonomy:[3/]

"1.00 Knowledge

1.10 Knowledge of Specifics
1.20 Knowledge of Ways and Means of Dealing with Specifics
1.30 Knowledge of the Universals and Abstractions in a Field

2.00 Comprehension

2.10 Translation
2.20 Interpretation
2.30 Extrapolation

3.00 Application

4.00 Analysis

4.10 Analysis of Elements
4.20 Analysis of Relationships
4.30 Analysis of Organizational Principles

1/Department of Education, op. cit., p. 97.

2/Paul L. Dressel and Clarence H. Nelson, Questions and Problems in Science: Test Item Folio No. 1, Cooperative Test Division, Educational Testing Service, Princeton, New Jersey, 1956, p. xiv.

3/B. S. Bloom, et al., op. cit.

5.00 Synthesis

5.10 Production of a Unique Communication
5.20 Production of a Plan, or Proposed Set of Objectives
5.30 Derivation of a Set of Abstract Relations

6.00 Evaluation

6.10 Judgments in Terms of Internal Evidence
6.20 Judgments in Terms of External Criteria"

This study is concerned with the measurement of learning outcomes of the first year of instruction guided by a new course of study. Consequently, it is proposed to limit the measurement to objectives 1, 2, and 3 in the above list and to construct an achievement test designed to evaluate student growth in knowledge of facts, concepts, and understanding of principles.

The history of such test construction is long and honorable. Published tests in the sciences are both numerous and varied. A lengthy report of the literature on this type of testing would be both repetitious and unnecessary. Therefore, this review will be confined to the listing of several excellent summaries and to the description of their applicability to the present study.

The Fourth Mental Measurements Yearbook [1/] is the one best source of information concerning published tests now available. An examination of test listed therein showed none which could be used to measure the desired outcomes of the Teachers Colleges' course in physical science.

1/Oscar K. Buros (Editor), The Fourth Mental Measurements Yearbook, Gryphon Press, Highland Park, New Jersey, 1953.

Guides to test construction.-- Because the construction of a new test specifically designed to measure some delimited learning outcomes was indicated, certain guides to test construction were consulted. The following were more than adequate for the purpose:

Hawks, Lindquist, and Mann, 1/ in an extensive survey of test construction, offer valuable information and guidance on the construction of science test items.

Smith and Tyler 2/ offer numerous sample exercises and test items on the application of science principles with suggestions and appropriate situations for their use.

In a later book, Ebel 3/ gives a very comprehensive set of directions on the writing of test items.

Dressel and Nelson 4/ offer a Test Item Folio of several thousand test items, classifying them under two general headings: Biological Sciences and Physical Sciences. These, in turn, are sub-divided into the specific areas of study. Within each subject-matter category, the items are further classified

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1/H. E. Hawks, E. F. Lindquist, and C. R. Mann (Editors), The Construction and Use of Achievement Examinations, Houghton Mifflin Company, Boston, 1936, Chapter 5.

2/Eugene R. Smith, Ralph W. Tyler, et al., Appraising and Recording Student Progress, McGraw-Hill Book Co., Inc., New York, 1942, pp. 77-111.

3/R. L. Ebel in E. F. Lindquist (Editor), Educational Measurement, American Council on Education, Washington, D. C., 1951, pp. 185-249.

4/Paul L. Dressel and Clarence H. Nelson, op. cit.

in sequence as to the cognitive levels of learning they purport to measure. This is the best single guide to a knowledge of the types of test items used and the specific knowledges emphasized at the college level.

The Forty-fifth Yearbook 1/ presents valuable material and sources of information on the problems of appraising understanding in the various subject matter fields. It also contains many worthwhile illustrative sample items.

Gerberich 2/ gives specimen items for various educational outcomes and classifies them by subject, form, type, variety, and educational level.

Trump and Haggerty 3/ give an extensive outline of procedures to be followed in the construction of various types of test items.

It was decided early in this study that the test to be constructed should consist of multiple-choice items. Mosier, Myers, and Price, 4/ in addition to offering numerous sugges-

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1/National Society for the Study of Education, The Measurement of Understanding, Forty-fifth Yearbook, 1946, Part I, The University of Chicago Press, Chicago.

2/J. R. Gerberich, Specimen Objective Test Items: A Guide to Achievement Test Construction, Longmans, Green and Co., New York, 1956.

3/J. B. Trump and Helen R. Haggerty, Basic Principles in Achievement Test Item Construction, Booklet, Personnel Research Section, Personnel and Research Procedure Branch, The Adjutant General's Office, Department of the Army (PRS Report 979), Washington, D. C., 1952.

4/C. I. Mosier, M. C. Myers, and Helen G. Price, "Suggestions for the Construction of Multiple-Choice Items," Educational and Psychological Measurement (March, 1945), 5:261-271.

tions for the improvement of this type of item, conclude that the more choices offered, the more reliable the item will be.

Use of tests to measure growth.-- After the test had been constructed, it was decided that, in addition to the more commonplace uses, it could measure growth of subject-matter understanding and also be used to locate specific areas in which growth did or did not take place.

Findley [1/] reviews some of the major trends in achievement testing. One very significant trend is that tests are increasingly used to measure growth and development rather than status at a particular time.

Dressel, [2/] in a list of questions pertinent to the problem of evaluation in general education, asks, "What is the optimum growth which may be expected for various kinds of students with regard to this objective?" The objective in question includes the understanding of concepts and principles.

Item analyses techniques.-- It was further decided, in order to implement the study of growth, that item analyses would be used. Comparison of item difficulties obtained from a pre-test at the beginning of the academic year and a post-test at the end of the year should give some indication of growth in the area of which the item is presumed to be a sample.

1/Warren G. Findley, "Progress in the Measurement of Achievement," Educational and Psychological Measurement (Summer, 1954), 14:255-260.

2/Paul L. Dressel, "Evaluation Procedures for General Education Objectives," The Educational Record (April, 1950), 31:97-122.

Flanagan [1] gives an outline of the procedures to be used in making item analyses.

Davis [2] in a later study found that indices of discrimination (Flanagan's coefficients) were considerably less reliable than indices of difficulty.

Fan [3] describes the construction of an item analysis table based on the per cent of correct responses in the highest 27 per cent group and the lowest 27 per cent group. The table estimates the per cent of correct answers to the item for the whole group, gives a discrimination index, and a statistic "delta" which is an index of item difficulty constructed on a linear scale. It was decided to use Fan's tables.

Previous testing program.-- The history of state-wide achievement testing in the State Teachers Colleges of Massachusetts is a very simple one. From 1944 through 1956, the colleges took part in the National College Sophomore Testing Program. The Cooperative General Culture Test, [4] which has a

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1/John C. Flanagan, "General Considerations in the Selection of Test Items and a Short Way of Estimating the Product-Moment Coefficient from Data at the Tails of the Distribution," Journal of Educational Psychology (March, 1939), 30:674-680.

2/Frederick G. Davis, "Notes on Test Construction: The Reliability of Item Analysis Data," Journal of Educational Psychology (October, 1946), 37:385-390.

3/Chung-Teh Fan, "Note on the Construction of an Item Analysis Table for the High-Low-27 per cent Group Method," Psychometrika (September, 1954), 19:231-237.

4/Educational Testing Service, Cooperative Test Division, General Culture Test, various forms, Princeton, New Jersey, 1944-1954.

sub-test on science, was given in all of the colleges. Bloom's[1] summary of his own review provides a condensed account of the limitations of this test:

> "Summary. In general, the test has many shortcomings. As a measure of general education, it is decidedly inadequate in both the subject-matter sampled and the types of objectives listed. For the most part, the emphasis is on knowledge rather than of the ability and skill objectives which are emphasized in A Design for General Education as well as in the other statements on general education. The knowledge is sampled by items which measure rather superficial acquaintance with the subject matter field listed. Although such knowledge may be a prerequisite to the more complex abilities and skills, only the most reckless test interpreter would claim that measurement of one provides a good index of the other.
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> As a test of acquaintance, with a great variety of subject matter, it is a useful test. As an index of the individual's general culture, general education, or liberal education, it is quite inadequate. Perhaps the major criticism of the test is that it attempts to do an almost impossible task--the measurement of the product of two or more years of education in 180 minutes."

Unfortunately, comparisons were made of the mean scores of the different colleges on this test, but no effort was made to measure growth.

Decision to test content.-- Dressel and Mayhew,[2] in giving reasons as to why they ignored the testing of content, stated that the variety of subject matter in the various science courses they had surveyed would make it difficult to

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1/Benjamin S. Bloom, "Review No. 4" in The Third Mental Measurement Yearbook, Oscar Buros, Editor, The Rutgers University Press, New Brunswick, New Jersey, 1949, p. 4.

2/Paul L. Dressel and Lewis B. Mayhew, op. cit., p. 104.

establish a common denominator for subject matter testing.

The situation in the Teachers Colleges of Massachusetts is unique in that a common denominator does exist in the form of a physical science course which is a required part of the general education of all prospective elementary school teachers.

Scates [1/] remarked that "the modern measurement movement was not developed by teachers and consequently does not supply teachers with goals or effective aids."

The measuring instrument presented here was prepared by a teacher; other teachers in the same subject area approved of the items and the objective; and all teachers concerned were informed of test results and interpretations.

1/Douglas E. Scates, "Fifty Years of Objective Measurement and Research in Education," Journal of Educational Research (December, 1947), 41:241-264.

CHAPTER III

CONSTRUCTING AND ADMINISTERING THE TEST

Selecting the test items.-- The first step in the construction of the test was the preparation of a guide list of 314 five-choice multiple-choice items which were designed to sample adequately the facts, concepts, and principles indicated by the Teachers Colleges' course outline of physical science.

A list of physical science concepts prepared by Wise [1] served to delineate further the concepts of the course outline. His list was established by having it checked by a jury of experts as to the relevance and importance of the concepts it contained and by then listing the concepts in descending order of their frequency of mention.

As the course outline does not include coverage of the areas of earth science, climatology, and meteorology, the concepts in these areas on Wise's list were not consulted. Thus the guide list was established by checking the course of study, the outcomes of which the final test would attempt to measure, and by consulting a highly reputable and established list of physical science concepts.

1/Harold E. Wise, "A Determination of the Relative Importance of Principles of Physical Science for General Education, Science Education (December, 1941), 25:371-379.

The items on the guide list were used in appropriate quarter and semester examinations at College 1. The per cent of correct responses to each item was calculated and those items answered correctly by fewer than 14 per cent and by more than 86 per cent of this group were discarded. Students were asked to indicate items which seemed to be ambiguously worded. Some of these were discarded, others were rewritten. The result was a MASTER LIST[1/] of 230 items.

This MASTER LIST of questions was then submitted to 223 students in Colleges 1, 2, and 3.

Correlation of MASTER LIST items with other factors.-- Scores on the Gamma Test of the *Otis Quick-Scoring Mental Ability Test*; the sub-test on the Ability to do Quantitative Thinking of the *Iowa Tests of Educational Development*; and sub-tests on Vocabulary, Speed of Comprehension, Mechanics of Expression of the *Cooperative English Test C_2 Form T* were available for the students in this criterion group. As a negative form of validation, the raw scores that students obtained on the MASTER LIST were converted to stanines and correlated with their stanine scores on each of the above tests.

Use of stanines.-- Stanines were used to insure comparability and to simplify statistical analysis. A stanine ("sta" for standard and "nine" for 9) is a simple type of standard score which is based on the assumption that the underlying distribution of the trait measured is a normal curve or that

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1/See Apendix A, p. 103.

the treatment of the score distribution as if the trait were normally distributed will not result in any serious distortion of fact. The mean score of the stanine distribution is 5 and the standard deviation is 2. Since stanines are directly comparable when based on the same population, the performances on these several variables can be directly compared. The inference is that if the correlations are low, the MASTER LIST measures something other than what is measured by these tests.

Consumer validity.-- In order to insure some degree of consumer validity, the MASTER LIST of items was submitted to a jury consisting of one physical science instructor from each of the colleges. These jurors were asked to rate each item on the list by the following five point scale:

Jury Rating Scale

5 - very important concept in course

4 - important concept in course

3 - has some merit as concept in course

2 - acceptable, but of minor importance

1 - not acceptable

It was agreed with the jury that any item with a rating of less than three would not be included in the final forms of the test.

Initial item analyses.-- The answers to the items on the MASTER LIST were then item-analyzed using the Fan [1/] tables. These tables, which are an extension of the Flanagan tables,

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1/Chung-Teh Fan, Item Analysis Table, Educational Testing Service, Princeton, New Jersey, 1952.

were originally prepared by Chung-Teh Fan for use by the Educational Testing Service. They provide a ready means of translating the observed proportion of successes in the upper 27 per cent and the lower 27 per cent into an estimate of item difficulty and a measure of item discrimination. The latter is the correlation, "r," between the criterion score, which forms the basis of the selection of the high and low 27 per cent groups, and the continuous score assumed to underlie responses to items. This statistic r is discussed in an article by Levy[1/] describing research at the Educational Testing Service. She states that all questions on a tryout item analysis with an r of less than 0.30 should be discarded. They were.

Two statistics are supplied as indices of difficulty. The first one is "p" which is the proportion of correct responses. It is computed from tables of the normal bivariate distribution. The second expression of item difficulty is expressed in terms of "delta" (Δ). Delta is related in the following manner to the normal deviate, x, corresponding to p:

$$\Delta = 13 + 4x$$

--where x is taken as positive for p's less than 0.50 and negative for p's greater than 0.50. Thus delta increases with item difficulty. Delta also expresses difficulty as a linear

1/Beatrice Levy, "Testing the Outcomes of Chemical Education," Journal of Chemical Education (January, 1951), 28:43-46.

quantity and thus permits comparisons to be made between groups taking different test forms.

Preparation of final test forms.-- Two forms, E and K, of 50 items each were prepared from the remaining pool of items so that they had comparable mean difficulties and standard deviations. Form E had a mean delta of 11.61 and a standard deviation of deltas of 1.94. Form K had a mean delta of 11.60 and a standard deviation of its deltas of 1.96. A delta of 11.6 corresponds to a p of 0.64. The implication followed that an average group of students should be able to answer correctly more than half of the items.

An effort was made in preparing the test forms to maintain a balance between subject matter content and the broader areas of knowledge and fact, science vocabulary, science history, and understanding of concepts. (See Table 3, page 31.)

The test forms were printed, and directions for taking the test were placed on the front page. The instructors giving the test were supplied with typed instructions informing them of the purpose of the test, asking them to read the printed instructions aloud to the students before starting the test, and advising them that they would be given the analyzed results of the first testing as soon as was practical.

International Business Machine Form I. T. S. 1100A 156 was used as an answer sheet. This form has space for answers to 150 five-choice questions. The directions asked that answers to both test forms be placed on this sheet. It should be noted that Form E has questions numbered from 1 to 50, while Form K has questions numbered from 101 to 150. The unused numbers 51 to 100 are reserved for any future lengthening of the test. It should also be noted that, in the directions, there was no penalty for guessing in the scoring of the items. Ruch and DeGraff 1/ found that the reliability of corrected guess scores, particularly where there are five choices, is not significantly different from uncorrected scores.

Finally, each college has a 120 minute period reserved for laboratory work. This period was used for the administration of the test so that there was sufficient time for the slowest student to answer all questions on both forms.

Administering the test.-- At the beginning of the 1957-1958 academic year, the test booklets and answer sheets were delivered to each of the participating colleges. During the first week of October, the tests were given to all available students majoring in elementary education. By the end of the month all colleges had received a report of the results of preliminary testing. The report included: the test scores of all students who had taken the test, a short statistical analysis of the raw scores, and the results of item analyses of both forms. The latter included an explanation of the statistics used with particular emphasis being placed on the

1/G. M. Ruch and M. H. DeGraff, "Corrections for Chance and 'Guess' versus 'Do Not Guess' Instructions in Multiple-Response Tests," Journal of Educational Psychology (September, 1926), 17:368-375.

meaning of the indices of difficulty.

Toward the end of the academic year, during the first two weeks in May of 1958, the same groups of students were tested again with the same test forms.

Collection of data.-- Raw scores, with no correction for guessing, were obtained. These raw scores were arranged in a population distribution and stanines were assigned for pre-test and post-test of Form E and of Form K and their totals. These data were then coded by individual, by college, by sex, and by test form and placed on Hollerith cards. Item analyses were made on the responses to Forms E and K for each college and the data so obtained were arranged in tables.

CHAPTER IV

ANALYSIS OF THE DATA

Preparation of the test.-- The scores obtained by the criterion group on the MASTER LIST of items were converted to stanine scores and these were compared with the stanine scores of standard tests of English ability, the ability to do quantitative thinking, and intelligence. These tests were the subtests on Vocabulary, Speed of Comprehension, and Mechanics of Expression of the A. C. E. Cooperative English Test, the Ability to do Quantitative Thinking of the Iowa Tests of Educational Development, and the gamma form of the Otis Quick-Scoring Test of Mental Ability. Table 1 shows the product-moment correlations from the comparison of the stanine scores of the above mentioned tests.

Table 1. Comparison of MASTER LIST Test Stanine Scores with Stanine Scores Available for Criterion Group Expressed in Product-Moment r's

English Vocabulary	Speed of Comprehension	Mechanics of Expression	Quantitative Thinking	Otis I.Q.
(1)	(2)	(3)	(4)	(5)
0.20	-0.14	0.09	0.16	0.18

The correlations between success in answering the MASTER LIST of items and English vocabulary, quantitative thinking ability, and Otis I. Q. are significantly greater than zero. Nevertheless, they are low enough to justify the statement that the items on the MASTER LIST most probably measure something other than intelligence, English ability, and the ability to do quantitative thinking. This offers a negative type of validity for the items concerned.

Table 2 shows the results of the item analyses of the MASTER LIST based on the responses of the criterion group along with the jury ratings for each item. The jury ratings represent the mean of the judgments of the jurors based on the five-point scale referred to in Chapter III.

Table 2. Item Analyses and Jury Ratings of MASTER LIST

Item Number	p	r	Δ	Jury Rating
(1)	(2)	(3)	(4)	(5)
1.	.54	.43	12.6	4.87
2.	.59	.41	12.1	4.80
3.	.77	.45	10.1	4.25
4.	.41	.51	13.9	3.87
5.	.62	.57	11.7	3.37
6.	.37	.66	14.4	3.87
7.	.48	.46	13.2	4.75
8.	.45	.26	13.5	5.00
9.	.57	.30	12.3	3.87
10.	.63	.00	11.7	4.50
11.	.50	.16	13.0	3.75
12.	.08	.25	18.6	3.87
13.	.55	.26	12.5	4.25
14.	.16	.29	17.0	4.25
15.	.84	.29	9.0	3.75

(continued on next page)

Table 2. (continued)

Item Number (1)	p (2)	r (3)	Δ (4)	Jury Rating (5)
16.	.55	.26	12.5	4.75
17.	.69	.24	11.0	3.00
18.	.69	.24	11.0	5.00
19.	.46	-.08	13.4	4.63
20.	.57	.22	12.3	5.00
21.	.90	.09	7.9	4.75
22.	.88	.18	8.3	4.13
23.	.31	.33	15.0	4.75
24.	.48	.46	13.2	4.00
25.	.65	.04	11.5	4.25
26.	.56	.04	12.4	4.50
27.	.65	.23	11.5	4.86
28.	.41	.34	13.9	4.87
29.	.39	.39	14.1	5.00
30.	.45	.50	13.0	4.63
31.	.31	.33	15.0	4.63
32.	.52	.04	12.8	4.50
33.	.90	.58	7.9	4.37
34.	.65	-.04	11.5	3.50
35.	.17	-.13	16.8	3.25
36.	1.00	.00	6.0	4.50
37.	.82	.20	9.4	4.63
38.	.78	.76	10.0	5.00
39.	.80	.55	9.6	4.25
40.	.73	.04	10.5	3.25
41.	.80	.55	9.6	4.75
42.	.95	.43	6.4	4.00
43.	.90	.31	7.8	4.13
44.	.59	.42	12.1	4.63
45.	.75	.10	10.3	3.63
46.	.40	.59	14.0	4.63
47.	.63	.10	11.7	4.50
48.	.48	.61	13.2	4.25
49.	.70	.57	10.9	4.50
50.	.60	.60	12.0	4.87

(continued on next page)

Table 2. (continued)

Item Number (1)	p (2)	r (3)	Δ (4)	Jury Rating (5)
51.	.75	.48	10.3	4.25
52.	.85	.45	8.8	4.50
53.	.35	.53	14.4	3.87
54.	.94	.54	7.5	4.87
55.	.54	.15	12.6	3.87
56.	.64	.44	11.6	3.50
57.	.53	.69	12.7	4.25
58.	.80	.55	9.6	4.50
59.	.25	.48	15.7	3.25
60.	.52	.12	12.8	4.00
61.	.38	.56	14.2	3.75
62.	.86	.24	8.7	4.50
63.	.84	.15	9.1	3.00
64.	.93	.40	7.1	5.00
65.	.69	.47	11.0	4.63
66.	.37	.27	14.3	2.87
67.	.46	.43	13.4	4.75
68.	.69	.33	11.0	4.13
69.	.35	-.06	14.5	3.87
70.	.56	.66	12.4	3.00
71.	.60	.66	12.0	4.00
72.	.59	.42	12.1	3.75
73.	.41	.51	13.9	4.25
74.	.71	.19	10.8	3.37
75.	,75	.21	10.3	4.25
76.	.21	.00	16.2	2.87
77.	.67	.28	11.2	3.87
78.	.33	.60	14.8	3.37
79.	.13	.41	17.5	3.25
80.	.53	.29	12.7	4.00
81.	.20	.23	16.3	3.37
82.	.43	.30	13.7	3.87
83.	.57	.38	12.3	3.75
84.	.27	.51	15.5	4.13
85.	.59	-.09	12.1	3.50

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Table 2. (continued)

Item Number (1)	p (2)	r (3)	Δ (4)	Jury Rating (5)
86.	.75	.48	10.3	4.00
87.	.50	.34	13.0	3.50
88.	.50	.50	13.0	3.50
89.	.71	.44	10.8	3.87
90.	.52	.46	12.8	4.13
91.	.69	.33	11.0	3.87
92.	.45	.26	13.5	3.13
93.	.59	.34	12.1	3.50
94.	.51	.25	12.9	3.50
95.	.45	.50	13.5	4.25
96.	.48	.54	13.2	3.75
97.	.59	.34	12.1	4.25
98.	.86	.09	8.8	3.00
99.	.76	.33	10.1	4.63
100.	.48	.46	13.2	4.13
101.	.84	.68	9.1	4.25
102.	.48	.46	13.2	3.86
103.	.57	.38	12.3	3.63
104.	.82	.52	9.3	4.13
105.	.67	.37	11.2	3.75
106.	.53	.29	12.7	3.75
107.	.55	.34	12.5	4.00
108.	.36	.44	14.4	3.75
109.	.65	.40	11.4	4.25
110.	.37	.10	14.3	3.13
111.	.30	.43	15.1	3.25
112.	.53	.29	12.7	3.87
113.	.88	.18	8.3	4.50
114.	.79	-.11	9.8	4.13
115.	.41	.51	13.9	3.81
116.	.57	.30	12.3	3.50
117.	.31	-.15	14.9	4.13
118.	.41	.18	13.9	3.63
119.	.52	.12	12.8	4.25

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Table 2. (continued)

Item Number (1)	p (2)	r (3)	Δ (4)	Jury Rating (5)
121.	.06	.45	19.3	3.00
122.	.73	.25	10.5	4.13
123.	.76	.31	10.2	4.25
124.	.41	.26	13.9	3.87
125.	.50	.42	13.0	3.37
126.	.86	.24	8.7	3.75
127.	.81	.37	9.5	4.13
128.	.76	.77	10.2	3.87
129.	.86	.66	8.7	4.25
130.	.64	.52	11.5	3.87
131.	.88	.31	8.2	4.00
132.	.75	.33	10.3	3.50
133.	.74	.65	10.4	3.37
134.	.71	.31	10.8	3.87
135.	.91	.56	7.7	3.63
136.	.85	.23	8.9	3.13
137.	.94	.16	6.9	4.25
138.	.64	.76	11.6	3.50
139.	.57	.35	12.3	3.25
140.	.34	-.19	14.6	2.87
141.	.77	.29	10.1	4.25
142.	.73	.66	10.6	4.13
143.	.78	.41	10.0	4.00
144.	.57	.35	12.3	3.50
145.	.71	.41	10.8	3.63
146.	.72	.16	10.7	3.37
147.	.57	.28	12.3	3.25
148.	.87	.42	8.6	3.87
149.	.81	.19	9.5	3.63
150.	.68	.35	11.1	3.50
151.	.26	.23	15.6	3.13
152.	.63	.45	11.7	3.87
153.	.82	.03	9.3	4.13
154.	.52	.18	12.8	3.87
155.	.68	.35	11.1	4.25

(continued on next page)

Table 2. (continued)

Item Number (1)	p (2)	r (3)	Δ (4)	Jury Rating (5)
156.	.81	.32	9.4	4.37
157.	.50	.30	13.0	3.63
158.	.69	.55	11.0	3.37
159.	.55	.31	12.5	3.87
160.	.31	.00	15.0	3.13
161.	.69	.55	11.0	4.13
162.	.79	.37	9.7	4.25
163.	.81	.53	9.4	4.25
164.	.46	.31	13.4	3.63
165.	.64	.32	11.6	4.13
166.	.95	.39	6.3	4.50
167.	.78	.59	10.0	4.25
168.	.31	.00	15.0	3.25
169.	.55	.31	12.5	3.37
170.	.45	-.40	13.5	2.75
171.	.79	.24	9.8	3.87
172.	.78	.59	10.0	3.50
173.	.46	-.12	13.4	3.37
174.	.00	.00	20.0	2.63
175.	.89	-.09	8.1	4.50
176.	.32	.24	14.9	3.63
177.	.46	.22	13.4	4.13
178.	.28	.16	15.3	3.25
179.	.83	.28	9.3	4.37
180.	.11	.59	18.0	3.37
181.	.38	.46	14.2	3.50
182.	.24	.19	15.9	3.87
183.	.68	.57	11.1	4.00
184.	.65	.29	11.4	3.87
185.	.25	.34	15.6	4.50
186.	.55	.13	12.5	4.25
187.	.33	.16	14.8	4.50
188.	.63	.55	11.7	4.63
189.	.79	.37	9.7	4.75
190.	.52	.35	12.3	3.75

(continued on next page)

Table 2. (continued)

Item Number (1)	p (2)	r (3)	Δ (4)	Jury Rating (5)
191.	.87	.16	8.5	3.87
192.	.55	.57	12.5	3.50
193.	.72	.51	10.7	4.25
194.	.61	.00	11.9	3.87
195.	.47	.60	13.3	4.13
196.	.53	.60	12.7	3.87
197.	.40	.40	14.0	4.13
198.	.66	.60	11.4	4.13
199.	.59	.32	12.1	3.13
200.	.92	.53	7.4	4.50
201.	.81	.72	9.5	4.37
202.	.46	.31	13.4	4.37
203.	.43	.36	13.7	3.63
204.	.48	.44	13.2	3.87
205.	.41	.32	13.9	3.25
206.	.41	.40	13.9	3.37
207.	.45	.05	13.5	3.63
208.	.52	-.18	12.8	4.13
209.	.45	.05	13.5	3.87
210.	.32	.35	14.9	3.87
211.	.59	-.04	12.1	4.00
212.	.59	.14	12.1	4.25
213.	.31	.21	15.0	3.63
214.	.64	.43	11.7	3.13
215.	.43	.18	13.7	4.25
216.	.17	.50	16.8	3.13
217.	.36	.32	14.4	3.37
218.	.78	.58	10.0	4.25
219.	.65	.29	11.4	4.50
220.	.81	-.07	9.5	4.13
221.	.88	.38	8.2	4.50
222.	.81	.19	9.5	4.25
223.	.46	.12	13.4	3.87
224.	.67	.48	11.3	4.00
225.	.76	.44	10.2	3.37

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Table 2. (concluded)

Item Number (1)	p (2)	r (3)	Δ (4)	Jury Rating (5)
226.	.50	.30	13.0	4.13
227.	.41	.22	13.9	3.37
228.	.87	.42	8.6	3.63
229.	.64	.14	11.6	3.37
230.	.59	.04	12.1	3.50

In the preparation of the two test forms, it was attempted not only to sample specific topics in the course, but also to balance coverage of the broader areas of scientific fact and vocabulary, understanding of concepts, and knowledge of the history of science. This distribution is shown in Table 3.

Table 3. Areas Sampled by Test Items

Scientific Fact and Vocabulary (1)	Understanding of Concepts (2)	History of Science (3)	Scientific Fact and Vocabulary (1)	Understanding of Concepts (2)
2	1	21	28	36
4	2	38	33	37
5	3	45	34	39
6	6	133	37	40
10	7	--	38	43
11	8	--	41	44
12	9	--	42	46
16	12	--	45	47
18	13	--	113	48
19	14	--	115	49
20	15	--	118	50
21	31	--	120	101
24	35	--	121	102

(concluded on next page)

Table 3. (concluded)

Scientific Fact and Vocabulary	Understanding of Concepts	History of Science	Scientific Fact and Vocabulary	Understanding of Concepts
(1)	(2)	(3)	(1)	(2)
125	103	--	148	119
127	104	--	--	121
131	105	--	--	122
132	106	--	--	124
133	107	--	--	126
134	108	--	--	128
135	109	--	--	129
136	110	--	--	130
137	111	--	--	139
140	112	--	--	141
142	114	--	--	144
143	117	--	--	146
147	118	--	--	150

Item analyses from results of testing.-- The following Tables 4 through 19 show the results of the item analyses of both forms of the test on both the pre-test and post-test.

Table 4. Item Analyses for Form E: Results for College 1

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	.09	.22	18.3	.34	.46	14.7
2	.29	.59	15.2	.57	.48	12.3
3	.35	.06	14.5	.52	.38	12.8
4	.50	-.04	13.0	.68	.41	11.2
5	.07	-.15	18.8	.13	.64	17.5
6	.34	.47	14.6	.82	.72	9.4
7	.68	.43	11.1	.76	.26	10.2
8	.67	.32	11.2	.64	.26	11.5
9	.25	.42	15.7	.52	.57	12.8
10	.21	.07	16.2	.40	.24	14.0

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Table 4. (continued)

Item Number	Pre-test p	r	Δ	Post-test p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
11	.11	.57	18.1	.49	.13	13.1
12	.28	.35	15.4	.55	.44	12.5
13	.50	.52	13.0	.46	.28	13.4
14	.09	.22	18.3	.23	.38	16.0
15	.07	-.15	18.8	.42	.20	13.8
16	.10	.00	18.1	.24	.12	15.8
17	.17	.45	16.8	.55	.34	12.5
18	.36	.15	14.5	.20	.33	16.3
19	.55	.05	12.5	.68	.18	11.1
20	.40	.34	14.0	.50	.42	13.0
21	.23	.26	16.0	.44	.33	14.1
22	.23	.26	16.0	.68	.41	11.2
23	.21	.21	16.2	.28	.35	15.4
24	.10	.57	18.1	.50	-.04	13.0
25	.23	.26	16.0	.78	.05	9.9
26	.65	.36	11.4	.57	.39	12.2
27	.50	.42	13.0	.88	.31	8.2
28	.19	.15	16.5	.66	.57	11.3
29	.20	.33	16.3	.41	.58	13.9
30	.21	.21	16.2	.62	.39	11.7
31	.45	.34	13.5	.55	.44	12.5
32	.45	.25	13.5	.50	.42	13.0
33	.10	.57	18.1	.50	.52	13.0
34	.67	.32	11.2	.73	.46	10.6
35	.43	.29	13.7	.75	.59	10.3
36	.38	.11	14.2	.45	.14	13.5
37	.43	.10	13.7	.49	.13	13.1
38	.09	.22	18.3	.64	.16.	11.6
39	.23	.38	16.0	.50	.52	13.0
40	.09	.22	18.3	.39	.42	14.1
41	.62	.30	11.7	.88	.31	8.2
42	.47	-.09	13.3	.68	.11	11.1
43	.06	-.46	19.2	.60	.44	12.0
44	.11	.30	17.9	.49	.22	13.1
45	.28	.35	15.4	.57	.29	12.3

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Table 4. (concluded)

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
46	.17	.23	16.9	.37	.38	14.3
47	.50	.14	13.0	.68	.41	11.2
48	.17	.23	16.9	.44	.32	13.6
49	.21	-.07	16.2	.35	.35	14.5
50	.15	.41	17.1	.36	.15	14.5

Table 5. Item Analyses for Form K: Results for College 1

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
101	.45	.68	13.5	.81	.29	9.4
102	.17	.23	16.9	.49	.32	13.1
103	.28	.35	15.4	.35	.59	14.5
104	.33	.32	14.8	.60	.53	12.0
105	.23	.26	16.0	.35	.35	14.5
106	.35	.06	14.5	.81	.29	9.4
107	.40	.05	14.0	.66	.57	11.4
108	.33	.21	14.7	.60	.53	12.0
109	.22	.76	16.0	.46	.28	13.4
110	.21	.05	16.1	.15	.41	17.1
111	.08	.53	18.6	.71	.34	10.7
112	.00	.00	20.0	.17	.23	16.9
113	.21	.21	16.2	.38	.00	18.2
114	.53	.29	12.7	.49	.22	13.1
115	.33	.21	14.7	.55	.34	12.5
116	.57	.29	12.3	.86	.65	8.6
117	.17	.23	16.9	.68	.41	11.2
118	.45	.44	13.5	.44	.32	13.6
119	.19	.49	16.5	.24	.12	15.8
120	.21	.07	16.2	.36	.26	14.5

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Table 5. (concluded)

Item Number	Pre-test p	Pre-test r	Pre-test Δ	Post-test p	Post-test r	Post-test Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
121	.21	.21	16.2	.68	.41	11.2
122	.09	-.22	18.3	.31	.27	15.0
123	.08	.53	18.6	.45	.14	13.5
124	.52	.00	12.8	.52	.27	12.8
125	.27	.46	15.4	.38	.63	14.2
126	.25	.31	15.7	.33	.31	14.7
127	.08	.26	18.5	.25	.42	15.7
128	.24	.00	15.8	.52	.27	12.8
129	.25	.31	15.7	.46	.28	12.0
130	.33	.32	14.8	.49	.22	13.1
131	.05	.00	19.6	.09	.54	18.5
132	.19	.15	16.5	.35	-.06	14.5
133	.19	.00	16.5	.38	.30	14.3
134	.24	.13	15.8	.32	.43	14.9
135	.19	.00	16.5	.47	.18	13.3
136	.21	.21	16.2	.40	.16	14.0
137	.08	.26	18.5	.27	.46	15.4
138	.43	.51	13.7	.68	.41	11.2
139	.52	.38	12.8	.43	.10	13.7
140	.25	.31	15.7	.64	.26	11.5
141	.19	.49	16.5	.60	.24	12.0
142	.12	.08	17.7	.83	.23	9.1
143	.16	-.08	16.9	.54	.12	12.6
144	.34	.47	14.6	.39	.42	14.1
145	.11	.30	17.9	.30	.39	15.1
146	.19	.49	16.5	.50	.52	13.0
147	.12	.08	17.7	.54	.22	12.6
148	.25	.42	15.7	.47	.47	13.3
149	.10	.00	18.1	.52	.17	12.8
150	.00	.00	20.0	.05	.41	19.6

Table 6. Item Analyses for Form E: Results for College 2

Item Number	Pre-test p	r	Δ	Post-test p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	.12	.27	17.7	.21	.41	16.2
2	.51	.25	12.9	.69	.47	11.1
3	.41	.06	13.9	.90	.09	7.9
4	.60	.20	12.0	.85	.28	8.9
5	.12	-.27	17.7	.15	-.26	17.2
6	.47	.44	13.3	.61	.32	11.8
7	.75	.00	10.4	.95	.43	6.5
8	.47	.32	13.3	.71	.24	10.7
9	.13	.63	17.6	.36	.64	14.5
10	.25	.16	15.7	.58	.07	12.2
11	.16	.10	17.0	.37	.49	14.4
12	.25	.16	15.7	.33	.08	14.7
13	.37	.40	14.4	.37	.49	14.4
14	.09	.17	18.3	.30	.17	15.1
15	.14	.34	17.3	.15	.66	17.2
16	.14	.34	17.3	.34	.25	14.6
17	.28	.07	15.3	.82	.35	9.4
18	.37	.27	14.3	.69	.17	11.1
19	.44	.00	13.6	.72	.41	10.6
20	.25	.16	15.7	.45	.32	13.5
21	.12	-.27	17.7	.58	.24	12.2
22	.25	.56	15.7	.69	.47	11.1
23	.16	.10	17.0	.41	.55	13.9
24	.25	.32	15.7	.54	.15	12.6
25	.41	-.06	13.9	.76	.35	10.2
26	.65	.54	11.5	.80	.75	9.6
27	.57	.51	12.3	.78	.43	9.9
28	.33	.48	14.8	.41	.09	13.9
29	.31	.29	15.0	.57	.65	12.3
30	.22	.51	16.0	.49	.53	13.1
31	.69	.00	11.1	.90	.57	7.8
32	.54	.19	12.6	.69	.17	11.1
33	.19	.18	16.6	.21	.74	16.2
34	.53	.44	12.7	.82	.71	9.4
35	.44	.00	13.6	.73	.08	10.6

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Table 6. (concluded)

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
36	.19	.72	16.5	.58	.24	12.2
37	.19	-.18	16.6	.41	-.09	13.9
38	.12	.27	17.7	.72	.54	10.7
39	.27	.38	15.4	.61	.60	11.9
40	.31	.15	14.9	.38	.17	14.2
41	.47	.32	13.3	.72	.41	10.6
42	.47	.44	13.3	.72	.80	10.6
43	.12	.62	17.7	.28	.54	15.3
44	.19	.18	16.6	.15	.26	17.2
45	.25	.32	15.7	.65	.54	11.5
46	.16	-.10	17.0	.53	.32	12.7
47	.47	.18	13.3	.76	.35	10.2
48	.17	.70	16.8	.67	.60	11.2
49	.30	.43	15.1	.60	.69	12.0
50	.31	.29	15.0	.30	.17	15.1

Table 7. Item Analyses for Form K: Results for College 2

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
101	.66	-.07	11.3	.92	.00	7.6
102	.40	.20	14.0	.72	.54	10.7
103	.37	.14	14.3	.58	.24	12.2
104	.31	.00	15.0	.72	.54	10.7
105	.19	.18	16.6	.69	.47	11.1
106	.50	.61	13.0	.90	.57	7.8
107	.57	.38	12.3	.95	.43	6.5
108	.50	-.12	13.0	.64	.54	11.5
109	.25	.00	16.0	.90	.09	7.9
110	.19	.00	16.5	.30	.36	15.2

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Table 7. (continued)

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
111	.12	.27	17.7	.37	.00	16.7
112	.12	-.27	17.7	.15	.26	17.2
113	.14	.34	17.3	.45	.32	13.5
114	.44	.12	13.6	.69	.17	11.1
115	.31	.15	14.9	.45	.32	13.5
116	.71	.44	10.8	.79	.27	9.7
117	.12	.27	17.7	.45	.32	13.5
118	.60	.75	12.0	.61	.60	11.9
119	.28	.59	15.4	.41	.55	13.9
120	.21	.25	16.2	.46	.46	13.4
121	.50	.61	13.0	.75	.48	10.3
122	.16	.10	17.0	.33	.08	14.7
123	.12	.27	17.7	.45	.17	13.5
124	.37	.40	14.4	.76	.35	10.2
125	.54	.32	12.6	.83	.71	9.3
126	.25	.32	15.7	.45	.32	13.5
127	.06	.00	19.2	.26	.09	15.5
128	.28	.23	15.3	.58	.07	12.2
129	.22	.75	16.1	.52	.71	12.8
130	.65	.54	11.5	.64	.65	11.6
131	.21	.25	16.2	.46	.46	13.4
132	.12	.27	17.7	.45	.32	13.5
133	.22	.08	16.1	.49	.24	13.1
134	.21	.25	16.2	.49	.39	13.1
135	.37	.14	14.3	.61	.32	11.8
136	.28	-.07	15.3	.73	.08	10.6
137	.06	.00	19.2	.37	.00	14.3
138	.40	.75	14.0	.78	.43	9.9
139	.34	.21	14.6	.78	.43	9.9
140	.33	.48	14.8	.58	.24	12.2
141	.33	.48	14.8	.49	.39	13.1
142	.21	.25	16.2	.44	.60	13.6
143	.22	.08	16.1	.46	.00	13.4
144	.21	.51	16.0	.80	.75	9.6
145	.22	.51	16.0	.42	.25	13.8

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Table 7. (concluded)

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
146	.25	.16	15.7	.53	.46	12.7
147	.28	.23	17.6	.34	.25	14.6
148	.13	.63	17.6	.33	.43	14.7
149	.14	.34	17.3	.42	.25	13.8
150	.00	.00	20.0	.00	.00	20.0

Table 8. Item Analyses for Form E: Results for College 3

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	.22	.40	16.1	.15	.51	17.2
2	.17	.28	16.8	.40	.43	14.0
3	.44	.06	13.6	.24	-.04	15.8
4	.59	.07	12.1	.70	.27	10.9
5	.09	.37	18.3	.08	.11	18.7
6	.14	.49	17.4	.83	.50	7.1
7	.77	.15	10.1	.86	.49	8.6
8	.47	.24	13.3	.45	.51	13.5
9	.14	.33	17.3	.17	.41	16.8
10	.26	.06	15.5	.26	.44	15.6
11	.22	.40	16.1	.92	-.11	7.3
12	.17	.28	16.8	.50	.36	13.0
13	.36	.23	14.4	.26	.15	15.6
14	.16	.05	16.9	.37	.37	14.4
15	.09	.15	18.4	.11	.23	18.0
16	.11	.25	17.8	.33	.23	14.8
17	.21	.28	16.2	.68	.08	11.2
18	.42	.34	13.8	.26	.44	15.6
19	.47	-.06	13.3	.14	.05	17.2
20	.19	.13	16.5	.34	.18	14.7

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Table 8. (concluded)

Item Number	Pre-test p	Pre-test r	Pre-test Δ	Post-test p	Post-test r	Post-test Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
21	.25	.18	15.7	.63	.47	11.7
22	.50	.18	13.0	.65	.58	11.4
23	.20	.16	16.3	.30	.03	15.0
24	.20	.16	16.3	.40	.30	14.0
25	.35	.32	14.6	.33	.16	14.8
26	.40	.33	14.1	.88	.27	8.3
27	.90	.40	7.9	.75	.33	10.3
28	.12	.44	17.8	.20	.32	16.4
29	.29	.27	15.2	.28	.31	15.3
30	.23	.15	15.9	.31	.26	15.0
31	.62	.39	11.7	.76	.13	10.2
32	.44	.25	13.6	.81	.19	9.5
33	.17	.28	16.8	.69	.30	11.1
34	.73	.50	10.6	.75	.50	9.8
35	.33	.42	14.8	.57	.42	12.3
36	.25	.45	15.7	.30	.24	15.1
37	.23	.07	15.9	.10	.00	18.1
38	.15	.67	17.1	.90	.38	9.8
39	.15	.00	17.1	.10	.40	18.1
40	.26	.00	15.6	.31	.26	15.0
41	.39	.40	14.1	.53	.48	12.7
42	.58	.16	12.2	.36	.00	13.2
43	.08	.33	18.6	.30	.34	15.1
44	.17	.28	16.8	.13	-.12	17.5
45	.22	.40	16.1	.43	.30	13.7
46	.16	.39	17.0	.20	.32	16.4
47	.47	.12	13.3	.56	.32	12.4
48	.13	.30	17.6	.57	.30	12.3
49	.21	.28	16.2	.35	.45	14.5
50	.22	.11	16.1	.18	-.06	16.7

Table 9. Item Analyses for Form K: Results for College 3

Item	Pre-test			Post-test		
Number	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
101	.58	.46	12.2	.85	.22	9.0
102	.29	.27	15.2	.37	.37	14.4
103	.21	.08	16.2	.35	.14	14.5
104	.24	.00	15.8	.37	.31	14.3
105	.22	.11	16.1	.19	.19	16.5
106	.41	.36	13.9	.43	.42	13.7
107	.44	.31	13.6	.55	.19	12.5
108	.30	.03	15.0	.35	.14	14.5
109	.31	.23	15.0	.47	.42	13.3
110	.19	-.04	16.4	.10	.40	18.1
111	.05	.11	19.6	.05	.42	19.7
112	.15	.19	17.1	.06	.00	19.2
113	.13	.17	17.4	.66	.49	11.3
114	.17	.28	16.8	.58	.33	12.2
115	.41	.42	13.9	.48	.25	13.2
116	.55	.28	12.5	.72	.71	10.7
117	.09	.00	18.4	.22	.26	16.1
118	.45	.40	13.5	.62	.14	11.8
119	.27	.32	15.4	.22	.50	16.2
120	.23	.07	15.9	.33	.56	14.7
121	.22	.19	16.1	.84	.55	9.1
122	.23	.36	15.9	.55	.27	12.5
123	.23	.07	15.9	.36	-.20	14.5
124	.40	.33	14.1	.72	.71	10.7
125	.33	.42	14.8	.54	.35	12.6
126	.32	.26	14.9	.40	.17	14.0
127	.52	.39	12.8	.40	.24	14.0
128	.19	.44	16.6	.30	.51	15.1
129	.14	.33	17.3	.37	.48	14.3
130	.32	.33	14.9	.54	.29	12.6
131	.14	.49	17.4	.08	.34	18.5
132	.18	.00	16.7	.02	-.10	19.8
133	.26	.14	15.5	.24	.12	15.8
134	.08	.33	18.6	.48	.39	13.2
135	.20	.16	16.3	.08	.34	18.5

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Table 9. (concluded)

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
136	.16	.25	17.0	.73	.28	10.5
137	.16	.05	17.0	.18	-.06	16.7
138	.37	.50	14.3	.66	.43	11.4
139	.38	.31	14.2	.77	.00	10.0
140	.25	.45	15.7	.30	.51	15.1
141	.09	.15	18.4	.35	.69	14.6
142	.15	.11	17.2	.15	.18	17.2
143	.15	.11	17.2	.18	.16	16.7
144	.16	.25	17.0	.33	.40	14.8
145	.22	.11	16.1	.33	.40	14.8
146	.11	.25	17.8	.19	.72	16.5
147	.25	.18	15.7	.09	.17	18.3
148	.18	.19	16.7	.10	.40	18.1
149	.05	.11	19.6	.06	.24	19.2
150	.06	.46	19.2	.00	.00	20.0

Table 10. Item Analyses for Form E: Results for College 4

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	.34	.34	14.7	.35	.11	14.6
2	.40	.46	14.0	.47	.45	13.3
3	.34	.14	14.6	.22	.75	16.1
4	.56	.06	12.4	.47	.25	13.3
5	.02	.04	19.8	.09	.54	18.5
6	.40	.39	14.0	.90	.58	7.9
7	.76	.33	10.1	.84	.42	9.0
8	.38	.42	14.2	.64	.48	11.6
9	.30	.43	15.1	.26	.44	15.6
10	.22	.17	16.1	.20	.73	16.4

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Table 10. (continued)

Item Number	Pre-test p	Pre-test r	Pre-test Δ	Post-test p	Post-test r	Post-test Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
11	.31	.29	15.0	.47	.55	13.3
12	.29	.40	15.2	.39	.42	14.1
13	.35	.43	14.6	.56	.60	12.4
14	.11	-.09	17.9	.07	.15	18.8
15	.20	.22	16.4	.21	.51	16.4
16	.19	.18	16.6	.30	.24	15.1
17	.31	.29	15.0	.70	.51	10.9
18	.32	.03	14.8	.39	.42	14.1
19	.48	.09	13.2	.47	.15	13.3
20	.22	.00	16.1	.45	.31	13.5
21	.52	.22	12.7	.53	.45	12.7
22	.45	.36	13.5	.28	.81	15.3
23	.19	.00	16.5	.34	.33	14.6
24	.25	.32	15.7	.26	.44	15.6
25	.41	.06	13.9	.35	.22	14.6
26	.58	.48	12.2	.59	.56	12.1
27	.73	.50	10.6	.76	.39	10.1
28	.16	.53	17.0	.44	.50	13.6
29	.18	.30	16.7	.30	.51	15.1
30	.23	.28	16.0	.24	.77	15.9
31	.62	.42	11.8	.60	.21	12.0
32	.40	.20	14.0	.55	.21	12.5
33	.20	.36	16.3	.38	.62	14.3
34	.61	.04	11.9	.61	.52	11.8
35	.37	.40	14.4	.44	.60	13.6
36	.34	.34	14.7	.32	.28	14.9
37	.28	.23	15.3	.12	.31	17.8
38	.16	.10	17.0	.44	.60	13.6
39	.17	.40	16.8	.50	.68	13.0
40	.22	.17	16.1	.24	.26	15.8
41	.47	.44	13.3	.61	.42	11.9
42	.42	.17	13.8	.30	.51	15.1
43	.05	.39	19.7	.20	.73	16.4
44	.20	-.04	16.3	.14	.37	17.4
45	.37	.08	14.3	.47	.35	13.3

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Table 10. (concluded)

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
46	.16	.10	17.0	.14	.37	17.4
47	.40	.26	14.0	.55	.31	12.5
48	.22	.51	16.0	.65	.59	11.5
49	.29	.26	15.2	.31	.67	15.0
50	.22	.00	16.1	.29	.35	15.2

Table 11. Item Analyses for Form K: Results for College 4

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
101	.63	.27	11.7	.82	.47	9.3
102	.38	.55	14.2	.53	.64	12.7
103	.39	.30	14.2	.50	.30	13.0
104	.36	.63	14.4	.57	.69	12.3
105	.26	.35	15.6	.27	.31	15.5
106	.55	.59	12.4	.71	.64	10.7
107	.57	.32	12.3	.53	.64	12.7
108	.33	.25	14.8	.40	.31	14.1
109	.35	.61	14.6	.43	.69	13.7
110	.13	.31	17.5	.32	.28	14.9
111	.06	.22	19.3	.12	-.10	17.6
112	.07	.09	18.8	.24	.26	15.8
113	.25	.16	15.7	.56	.60	12.4
114	.40	.20	14.0	.47	.64	13.3
115	.45	.36	13.5	.37	.05	14.3
116	.78	.51	10.0	.74	.44	10.4
117	.21	.25	16.2	.22	.21	16.1
118	.46	.56	13.4	.53	.45	12.7
119	.28	.30	15.4	.30	.12	15.1
120	.13	.31	17.5	.20	.73	16.4

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Table 11. (concluded)

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
121	.33	.48	14.8	.57	.69	12.3
122	.23	-.04	15.9	.20	.51	16.4
123	.14	.34	17.3	.33	.55	14.8
124	.36	.53	14.4	.47	.55	13.3
125	.43	.45	13.7	.35	.59	14.5
126	.22	.17	16.1	.19	.30	16.5
127	.07	.50	18.9	.07	.49	19.0
128	.31	.00	15.0	.38	.62	14.3
129	.18	.71	16.6	.26	.61	15.5
130	.46	.25	13.4	.45	.41	13.5
131	.10	.38	18.2	.19	.30	16.5
132	.12	-.45	17.7	.15	.18	17.2
133	.28	.15	15.3	.18	.47	16.7
134	.13	.31	17.5	.17	-.08	16.7
135	.25	.16	15.7	.30	.12	15.1
136	.42	.29	13.8	.37	.05	14.3
137	.12	-.14	17.6	.27	.31	15.5
138	.60	.32	12.0	.86	.67	8.8
139	.34	.21	14.6	.60	.00	12.0
140	.26	.19	15.5	.34	.33	14.6
141	.17	.56	16.8	.35	.59	14.5
142	.11	.42	17.9	.14	.65	17.3
143	.13	.31	17.5	.26	.44	15.6
144	.22	.17	16.1	.42	.26	13.8
145	.25	.32	15.7	.17	.24	16.8
146	.16	.38	17.0	.34	.44	14.7
147	.25	-.08	15.7	.15	.18	17.2
148	.21	.25	16.2	.21	.35	16.2
149	.16	.27	16.9	.14	.37	17.4
150	.07	-.09	18.8	.04	-.04	19.8

Table 12. Item Analyses for Form E: Results for College 5

Item	Pre-test			Post-test		
Number	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	.18	.39	16.6	.25	.45	15.7
2	.34	.20	14.7	.43	.45	13.7
3	.46	.00	13.4	.23	.29	15.9
4	.46	.21	13.4	.65	.29	11.4
5	.04	.00	19.6	.02	-.03	19.8
6	.50	.50	13.0	.88	.38	8.2
7	.69	.49	11.0	.85	.23	8.9
8	.62	.38	11.8	.48	.52	13.2
9	.23	.48	16.0	.42	.61	13.8
10	.23	.25	16.0	.26	.23	15.6
11	.19	.16	16.5	.35	.20	14.6
12	.23	.05	16.0	.52	.44	12.8
13	.56	.40	12.4	.66	.39	11.3
14	.12	.22	17.7	.11	.59	18.0
15	.11	.36	17.8	.19	.53	16.6
16	.05	.35	19.8	.34	.10	14.6
17	.78	.27	10.0	.61	.28	11.9
18	.43	.29	13.7	.48	.08	13.2
19	.35	.13	14.6	.50	.22	13.0
20	.37	.12	14.3	.39	.28	14.1
21	.65	.23	11.5	.64	.32	11.6
22	.35	.39	14.5	,38	.46	14.2
23	.23	.05	16.0	.22	.00	16.1
24	.37	.35	14.3	.50	.40	13.0
25	.43	.37	13.7	.32	.35	14.9
26	.89	.36	8.2	.98	.00	6.1
27	.66	.54	11.3	.92	.25	7.4
28	.08	.26	18.5	.50	.55	13.0
29	.30	.21	15.1	.32	.15	14.8
30	.21	.45	16.2	.35	.61	14.6
31	.76	.29	10.2	.68	.05	11.1
32	.30	.29	15.1	.50	.21	13.0
33	.07	.21	18.8	.50	.48	13.0
34	.62	.38	11.8	.70	.32	10.9
35	.37	.12	14.3	.37	.15	14.3

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Table 12. (concluded)

Item Number	Pre-test p	Pre-test r	Pre-test Δ	Post-test p	Post-test r	Post-test Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
36	.34	.20	14.7	.43	.45	13.7
37	.18	.22	16.7	.45	.32	13.5
38	.12	.22	17.7	.39	.19	14.1
39	.27	.22	15.5	.17	.50	16.8
40	.27	.22	15.5	.25	.33	15.7
41	.12	.22	17.7	.48	.52	13.2
42	.41	-.04	13.9	.41	.40	13.9
43	.16	.17	17.0	.33	.48	14.8
44	.07	.00	18.9	.08	.25	18.6
45	.24	.50	15.8	.41	.40	13.9
46	.28	.25	15.3	.22	.59	16.0
47	.35	.23	14.5	.74	.79	10.5
48	.18	.71	16.6	.63	.55	11.7
49	.21	.30	16.3	.31	.44	15.0
50	.19	.04	16.4	.17	.28	16.8

Table 13. Item Analyses for Form K: Results for College 5

Item Number	Pre-test p	Pre-test r	Pre-test Δ	Post-test p	Post-test r	Post-test Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
101	.67	.00	11.2	.57	.36	12.3
102	.55	.18	12.5	.72	.67	10.7
103	.41	.04	13.9	.38	.36	14.2
104	.28	.67	15.3	.48	.52	13.2
105	.25	-.10	15.7	.28	.51	15.3
106	.61	.22	11.9	.83	.38	8.2
107	.66	.03	11.4	.68	.35	11.1
108	.21	.10	16.2	.52	.08	12.8
109	.27	.22	15.5	.59	.31	12.1
110	.29	.00	15.2	.35	.20	14.6

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Table 13. (continued)

Item Number	Pre-test p	Pre-test r	Pre-test Δ	Post-test p	Post-test r	Post-test Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
111	.12	.22	17.7	.06	.46	19.2
112	.03	.28	19.9	.11	.09	17.9
113	.14	.66	17.3	.59	.40	12.1
114	.30	.21	15.1	.35	.20	14.6
115	.37	.35	14.3	.65	.20	11.4
116	.70	.41	11.0	.92	.25	7.4
117	.10	.58	18.1	.27	.27	15.4
118	.48	.32	13.2	.62	.36	11.8
119	.26	.40	15.6	.21	.24	16.2
120	.24	.29	15.8	.26	.48	15.5
121	.37	.35	14.3	.87	.42	8.6
122	.30	.13	15.1	.29	.41	15.2
123	.11	.36	17.8	.23	.29	15.9
124	.31	.49	15.0	.57	.44	12.3
125	.54	.43	12.6	.50	.65	13.0
126	.18	.39	16.6	.37	.24	14.4
127	.10	.33	18.1	.12	.62	17.7
128	.24	.37	15.9	.35	.29	14.6
129	.24	.50	15.8	.37	.63	14.3
130	.52	.31	12.8	.65	.42	11.5
131	.07	.21	18.8	.23	.17	15.9
132	.10	.16	18.1	.12	.38	17.8
133	.46	-.15	13.4	.17	.28	16.8
134	.59	.33	12.0	.45	.21	13.5
135	.21	.30	16.3	.27	.27	15.4
136	.73	-.05	10.5	.57	.27	12.3
137	.25	.18	15.7	.12	.38	17.8
138	.54	.64	12.6	.72	.67	10.7
139	.36	.15	14.5	.68	-.05	11.1
140	.22	.34	16.0	.73	.27	10.6
141	.20	.42	16.4	.48	.36	13.2
142	.10	.33	18.1	.19	.72	16.5
143	.21	.21	16.2	.43	.36	13.7
144	.37	.35	14.3	.50	.55	13.0
145	.22	.34	16.0	.52	.00	12.8

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Table 13. (concluded)

Item Number	Pre-test p	Pre-test r	Pre-test Δ	Post-test p	Post-test r	Post-test Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
146	.20	.43	16.3	.35	.52	14.5
147	.19	.27	16.5	.22	.59	16.0
148	.15	.31	17.1	.17	.70	16.7
149	.15	.45	17.2	.57	.44	12.3
150	.08	-.26	18.5	.05	.39	19.7

Table 14. Item Analyses for Form E: Results for College 6

Item Number	Pre-test p	Pre-test r	Pre-test Δ	Post-test p	Post-test r	Post-test Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	.38	.34	14.2	.37	.16	14.3
2	.61	.41	11.9	.72	.45	10.7
3	.41	.15	13.9	.39	.37	14.1
4	.66	.10	11.4	.71	.00	10.8
5	.11	.19	17.9	.04	.54	19.7
6	.47	.55	13.3	.73	.43	10.5
7	.74	.31	10.4	.84	.17	9.0
8	.47	.16	13.3	.55	.53	12.5
9	.42	.26	13.8	.47	.47	13.3
10	.27	.06	15.4	.21	-.07	16.2
11	.24	.21	15.9	.18	.24	16.6
12	.19	.10	16.5	.35	.44	14.5
13	.59	.29	12.1	.43	.39	13.8
14	.05	-.24	19.8	.10	.26	18.1
15	.31	.37	15.0	.22	.33	16.1
16	.18	.24	16.6	.16	.00	17.0
17	.59	.33	12.0	.71	.38	10.8
18	.54	.30	12.6	.46	.39	13.4
19	.71	.32	10.8	.56	.03	12.4
20	.48	.32	13.2	.47	.13	13.3

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Table 14. (concluded)

Item Number	Pre-test p	Pre-test r	Pre-test Δ	Post-test p	Post-test r	Post-test Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
21	.74	.31	10.4	.68	.21	11.1
22	.33	.18	14.8	.36	.31	14.4
23	.34	.20	14.7	.20	.12	16.4
24	.30	.48	15.1	.49	.50	13.1
25	.42	-.02	13.8	.48	.21	13.2
26	.63	.42	11.6	.89	.00	8.2
27	.65	.44	11.5	.91	.54	7.5
28	.47	.09	13.3	.38	.48	14.2
29	.37	.16	14.3	.31	.37	15.0
30	.18	.06	16.7	.21	.15	16.2
31	.60	.21	12.0	.68	.07	11.1
32	.40	.43	14.0	.58	.34	12.2
33	.18	.39	16.6	.27	.42	15.5
34	.78	.34	10.0	.83	.20	9.1
35	.37	.37	14.4	.52	.33	12.8
36	.33	.36	14.7	.55	.28	12.5
37	.25	.05	15.7	.25	.04	15.6
38	.10	.48	18.0	.48	.38	13.1
39	.34	.33	14.6	.34	.35	14.6
40	.31	-.02	15.0	.15	.28	17.1
41	.59	.20	12.1	.57	.43	12.3
42	.51	-.02	12.9	.41	.07	13.9
43	.05	.39	19.7	.18	.47	16.7
44	.15	-.04	17.1	.04	.10	19.7
45	.34	.25	14.7	.41	.07	13.9
46	.12	.22	17.7	.15	.39	17.2
47	.45	.32	13.5	.51	.35	12.9
48	.15	.57	17.2	.29	.26	15.2
49	.25	.25	15.6	.29	.26	15.2
50	.16	.00	17.0	.10	.26	18.1

Table 15. Item Analyses for Form K: Results for College 6

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
101	.67	.14	11.2	.65	-.13	11.4
102	.49	.48	13.2	.55	.49	12.5
103	.47	.09	13.3	.42	.25	13.8
104	.30	.48	15.1	.46	.44	13.4
105	.24	.16	15.9	.19	.00	16.5
106	.44	.44	13.6	.84	.30	9.1
107	.58	.13	12.2	.70	.48	10.9
108	.40	.17	14.0	.31	.37	15.0
109	.27	.22	15.5	.34	.55	14.6
110	.12	.14	17.6	.21	.24	16.2
111	.05	.39	19.7	.21	.24	16.2
112	.05	.39	19.7	.08	.34	18.5
113	.19	.34	16.5	.34	.42	14.7
114	.50	.32	13.0	.52	.21	12.8
115	.50	.32	13.0	.47	.29	13.3
116	.60	.02	12.0	.79	.13	9.8
117	.18	.24	16.6	.32	.24	14.9
118	.49	.48	13.1	.56	.26	12.4
119	.17	.29	16.8	.26	.27	15.5
120	.33	.14	14.8	.27	.37	15.5
121	.36	.05	14.4	.32	.46	14.9
122	.25	.13	15.7	.21	.07	16.2
123	.07	.21	18.8	.17	.21	16.8
124	.45	.24	13.5	.64	.15	11.5
125	.35	.49	14.5	.48	.21	13.2
126	.27	.28	15.5	.31	.30	14.9
127	.06	.32	19.3	.10	.26	18.1
128	.26	.20	15.6	.29	.41	15.2
129	.33	.53	14.8	.36	.52	14.5
130	.59	.23	12.1	.65	.36	11.4
131	.19	.41	16.5	.22	.27	16.0
132	.06	.32	19.3	.04	.21	19.7
133	.26	.09	15.3	.24	.14	15.8
134	.14	.29	17.3	.20	.12	16.4
135	.32	.16	14.9	.31	.22	15.0

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Table 15. (concluded)

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
136	.63	.08	11.7	.45	.25	13.5
137	.47	.34	13.3	.44	.20	13.6
138	.56	.50	12.4	.72	.23	10.7
139	.40	.43	14.0	.54	-.06	12.6
140	.29	.11	15.2	.29	.13	15.2
141	.16	.60	17.0	.46	.39	13.4
142	.13	.25	17.5	.26	.18	15.6
143	.13	-.17	17.4	.44	.02	13.6
144	.23	.09	15.9	.28	.44	15.3
145	.15	.16	17.1	.25	.24	15.7
146	.14	.00	17.3	.36	.52	14.5
147	.29	.23	15.2	.07	.21	19.0
148	.19	.32	16.6	.20	.28	16.4
149	.13	.41	17.5	.12	.34	17.6
150	.05	.28	19.6	.04	.07	19.3

Table 16. Item Analyses for Form E: Results for College 7

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	.45	.29	13.5	.38	.34	14.2
2	.30	.34	15.1	.54	.47	12.6
3	.39	.12	14.1	.42	.15	13.8
4	.64	.17	11.5	.62	.26	11.7
5	.30	.19	15.1	.13	.54	17.6
6	.36	.40	14.5	.52	.43	12.8
7	.76	.35	10.2	.68	.33	11.1
8	.50	.26	13.0	.49	.23	13.1
9	.21	.24	16.2	.24	.37	15.9
10	.24	.04	15.8	.20	.35	16.4

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Table 16. (continued)

Item Number	Pre-test p	Pre-test r	Pre-test Δ	Post-test p	Post-test r	Post-test Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
11	.25	.28	15.6	.29	.47	15.2
12	.23	.08	16.0	.28	.12	15.3
13	.29	.27	15.2	.35	.41	14.5
14	.10	.34	18.0	.13	.08	17.5
15	.07	.19	19.0	.15	.52	17.1
16	.22	.30	16.1	.23	.25	16.0
17	.38	.33	14.2	.65	.40	11.4
18	.44	.26	13.6	.68	.33	11.1
19	.66	.21	11.4	.44	.12	13.6
20	.36	.20	14.5	.41	.20	13.9
21	.55	.27	12.5	.62	.26	11.7
22	.22	.37	16.0	.22	.34	16.0
23	.38	.26	14.3	.32	.29	14.8
24	.26	.36	15.5	.45	.32	13.5
25	.26	.10	15.5	.35	.23	14.5
26	.42	.47	13.9	.60	.39	12.0
27	.64	.36	11.5	.80	.51	9.6
28	.19	.13	16.5	.28	.45	15.3
29	.24	.31	15.8	.24	.34	15.8
30	.20	.21	16.4	.22	.51	16.0
31	.61	.38	11.9	.63	.30	11.6
32	.42	.34	13.8	.42	.13	13.8
33	.17	.49	16.9	.44	.60	13.6
34	.63	.23	11.7	.65	.42	11.5
35	.32	.23	14.9	.49	.41	13.1
36	.24	.40	15.8	.33	.24	14.7
37	.28	.04	15.3	.21	.21	16.2
38	.20	.24	16.4	.63	.38	11.7
39	.25	.23	15.8	.29	.52	15.3
40	.26	.09	15.5	.41	.45	13.9
41	.57	.32	12.3	.60	.52	12.0
42	.48	.12	13.2	.32	.29	14.8
43	.06	.07	19.3	.26	.51	15.6
44	.11	.00	17.9	.10	.07	18.0
45	.20	.28	16.4	.34	.27	14.7

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Table 16. (concluded)

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
46	.17	.21	16.8	.15	.41	17.1
47	.42	.18	13.8	.53	.22	12.7
48	.11	.35	17.9	.33	.25	14.8
49	.25	.18	15.7	.31	.50	15.0
50	.20	.22	16.4	.21	.13	16.2

Table 17. Item Analyses for Form K: Results for College 7

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
101	.61	.28	11.9	.77	.32	10.1
102	.45	.56	13.5	.38	.27	14.2
103	.34	.28	14.6	.49	.38	13.1
104	.23	.36	15.9	.37	.49	14.4
105	.22	.17	16.1	.12	-.12	17.7
106	.31	.27	15.0	.63	.34	11.7
107	.44	.22	13.6	.51	.14	12.9
108	.23	.36	15.9	.31	.47	15.0
109	.36	.36	14.5	.38	.57	14.3
110	.17	.23	16.9	.36	.41	14.4
111	.04	.04	19.6	.10	.07	18.0
112	.04	.04	19.6	.04	-.10	19.7
113	.18	.52	16.6	.30	.73	15.1
114	.45	.23	13.5	.54	.41	12.6
115	.55	.24	12.5	.54	.35	12.6
116	.60	.19	12.0	.68	.28	11.1
117	.08	.31	18.7	.26	.61	15.5
118	.40	.29	14.0	.44	.36	13.6
119	.23	.20	15.9	.37	.59	14.3
120	.17	.21	16.8	.19	-.07	16.5

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Table 17. (concluded)

Item Number	Pre-test p	Pre-test r	Pre-test Δ	Post-test p	Post-test r	Post-test Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
121	.21	.30	16.3	.68	.54	11.2
122	.18	.17	16.6	.13	.06	17.4
123	.12	.16	17.8	.43	.33	13.4
124	.30	.32	14.2	.44	.35	13.6
125	.20	.60	16.4	.25	.56	15.7
126	.20	.21	16.4	.22	.21	16.1
127	.07	.19	19.0	.11	.51	17.8
128	.18	.27	16.7	.41	.30	13.9
129	.08	.53	18.6	.21	.40	16.3
130	.34	.32	14.7	.47	.36	13.3
131	.18	.27	16.7	.22	.12	16.0
132	.47	.24	13.3	.51	.14	12.9
133	.15	.16	17.1	.20	-.07	16.3
134	.13	.24	17.6	.45	.47	13.6
135	.51	.34	12.9	.63	.15	11.7
136	.28	.29	15.3	.43	.21	13.7
137	.13	.09	17.4	.13	.31	17.5
138	.44	.34	13.6	.68	.25	11.2
139	.42	.30	13.8	.67	.03	11.3
140	.27	.32	15.4	.42	.15	13.8
141	.14	.43	17.4	.43	.42	13.7
142	.13	.09	17.4	.17	.28	16.8
143	.15	.28	17.1	.21	.11	16.2
144	.21	.14	16.3	.25	.38	15.7
145	.18	.27	16.7	.30	.39	15.1
146	.10	.16	18.1	.35	.53	14.6
147	.25	-.05	15.7	.24	.29	15.8
148	.18	.17	16.6	.11	.29	17.9
149	.08	.34	18.5	.20	.28	16.4
150	.05	.39	19.7	.08	-.17	18.7

Table 18. Item Analyses for Form E: Results for College 8

Item Number	Pre-test p	r	Δ	Post-test p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	.17	.37	16.8	.17	.37	16.8
2	.35	.51	14.6	.32	.26	14.9
3	.46	-.07	13.4	.34	.00	14.6
4	.48	.50	13.2	.53	.32	12.7
5	.07	.00	18.9	.05	.16	19.6
6	.39	.36	14.1	.93	.30	7.2
7	.64	.29	11.6	.77	.65	10.1
8	.48	.17	13.2	.49	.19	13.1
9	.31	.27	15.0	.35	.32	14.6
10	.17	.00	16.8	.19	.06	16.5
11	.25	.05	15.7	.17	.37	16.8
12	.21	.04	16.2	.38	.47	14.2
13	.38	.39	14.3	.38	.24	14.2
14	.11	.06	17.8	.02	-.02	19.8
15	.10	.57	18.2	.10	-.16	18.1
16	.20	.09	16.4	.28	.28	15.3
17	.21	.04	16.2	.40	.07	14.0
18	.29	.31	15.2	.51	.08	12.9
19	.65	.04	11.5	.42	.10	13.8
20	.33	.23	14.8	.37	.28	14.4
21	.17	.37	16.8	.12	.44	17.8
22	.48	.43	13.2	.45	.43	13.5
23	.37	.22	14.4	.27	.16	15.4
24	.15	.18	17.2	.98	.00	6.2
25	.23	.00	16.0	.60	.20	12.0
26	.57	.21	12.3	.71	.22	10.8
27	.80	.33	9.7	.80	.36	9.6
28	.16	.12	16.9	.19	.15	16.5
29	.36	.36	14.5	.34	.22	14.7
30	.16	.22	17.0	.44	.48	13.6
31	.57	.21	12.3	.57	.40	12.3
32	.33	.15	14.7	.33	.29	14.7
33	.09	.54	18.5	.08	.31	18.7
34	.78	.37	10.0	.76	.00	14.6
35	.40	.21	14.0	.43	.33	13.7

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Table 18. (concluded)

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
36	.14	.50	17.3	.30	.15	15.1
37	.22	.14	16.1	.32	.11	14.9
38	.10	.40	18.1	.68	.13	11.2
39	.16	.22	17.0	.22	.37	16.0
40	.22	.27	16.0	.15	.19	17.1
41	.27	.25	15.5	.38	.24	14.2
42	.45	.25	13.5	.59	.30	12.1
43	.05	-.16	19.6	.22	.37	16.0
44	.26	.09	15.5	.08	.08	18.5
45	.28	.21	15.3	.65	.42	11.5
46	.30	.24	15.1	.10	.16	18.1
47	.36	.14	14.4	.35	.32	14.6
48	.20	.33	16.3	.18	.27	16.7
49	.30	.24	15.1	.30	.41	15.0
50	.18	.16	16.7	.12	.21	17.8

Table 19. Item Analyses for Form K: Results for College 8

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
101	.69	.45	11.1	.73	.08	10.6
102	.29	.40	15.2	.30	.32	15.1
103	.30	.00	15.1	.38	.18	14.2
104	.33	.37	14.8	.27	.45	15.5
105	.27	.45	15.5	.12	.44	17.8
106	.46	.47	13.4	.63	.28	11.6
107	.45	.16	13.5	.62	.24	11.8
108	.33	.08	14.7	.17	.55	16.8
109	.36	.29	14.4	.30	.22	15.1
110	.17	.00	16.8	.22	.14	16.1

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Table 19. (continued)

Item Number	Pre-test			Post-test		
	p	r	Δ	p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
111	.05	.41	19.6	.06	.47	19.1
112	.05	-.41	19.6	.03	.28	19.8
113	.17	.37	16.8	.29	.39	15.2
114	.41	.24	13.9	.30	.22	15.1
115	.42	.31	13.8	.37	.36	14.3
116	.70	.43	10.9	.72	.29	10.7
117	.09	.54	18.5	.30	.32	15.1
118	.36	.29	14.4	.29	.39	15.2
119	.30	.07	15.1	.25	.11	15.6
120	.20	.33	16.3	.13	.47	17.5
121	.31	.27	15.0	.30	.59	15.1
122	.15	.18	17.2	.27	.07	15.5
123	.18	.16	16.7	.12	.21	17.8
124	.45	.45	13.5	.44	.30	13.6
125	.24	.31	15.8	.41	.36	13.9
126	.22	.37	16.0	.20	-.10	16.3
127	.06	.24	19.2	.24	.39	15.9
128	.18	.16	16.7	.30	.15	15.1
129	.15	.52	17.1	.25	.30	15.7
130	.42	.41	13.8	.33	.15	14.7
131	.15	.07	17.1	.11	.41	18.0
132	.11	-.06	17.8	.00	.00	20.0
133	.20	.21	16.4	.12	-.08	17.7
134	.13	.64	17.5	.30	.32	15.1
135	.23	.17	15.9	.22	.14	16.1
136	.20	.21	16.4	.46	.39	13.4
137	.09	.36	18.4	.12	.62	17.7
138	.54	.28	12.6	.77	.52	10.0
139	.43	.13	13.7	.57	.26	12.3
140	.25	.21	15.7	.32	-.05	14.9
141	.20	.00	16.4	.25	.43	15.6
142	.10	.14	18.2	.11	.60	17.9
143	.13	.25	17.5	.16	.53	17.0
144	.33	.23	14.8	.17	.37	16.8
145	.16	.22	17.0	.28	.28	15.3

(concluded on next page)

Table 19. (concluded)

Item Number	Pre-test p	r	Δ	Post-test p	r	Δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
146	.77	-.09	16.8	.19	.30	16.5
147	.18	-.05	16.6	.22	.22	16.1
148	.30	.17	15.1	.19	.06	16.5
149	.05	-.41	19.6	.19	.30	16.5
150	.05	.16	19.6	.06	.24	19.2

Means and standard deviations were calculated for the statistic delta in each of the above tables and are shown in Tables 20 and 21. In addition, these two tables have a column containing the standard deviation of the differences of deltas from the pre-test to the post-test.

Table 20. Distribution Statistics for Deltas: Form E

College	Pre-test Mean	Pre-test Standard Deviation	Post-test Mean	Post-test Standard Deviation	Standard Deviation Differences
(1)	(2)	(3)	(4)	(5)	(6)
1	15.44	2.99	12.69	1.91	1.99
2	15.09	1.90	12.30	2.50	1.50
3	15.25	2.19	13.71	2.18	2.92
4	14.97	1.95	14.02	1.87	1.71
5	15.01	2.53	13.65	2.63	1.98
6	14.37	2.34	13.92	2.74	1.57
7	14.97	1.99	14.21	1.96	1.41
8	15.26	2.13	14.53	2.83	2.60
All Colleges	15.04	0.30	13.63	0.62	1.03

The low standard deviations for all colleges is explained for this and the following table by the increase in the number of cases to 884. These deviations also suggest that the total population is more homogeneous than the groups of which it is composed.

Table 21. Distribution Statistics for Deltas: Form K

College	Pre-test Mean	Pre-test Standard Deviation	Post-test Mean	Post-test Standard Deviation	Standard Deviation Differences
(1)	(2)	(3)	(4)	(5)	(6)
1	16.09	1.85	13.45	2.29	1.96
2	15.42	2.05	12.41	2.49	1.70
3	16.02	1.72	14.70	2.86	2.29
4	15.56	1.59	14.68	2.27	1.25
5	15.31	2.22	13.88	2.65	1.23
6	15.44	2.24	14.65	2.34	1.63
7	16.01	1.99	14.69	1.94	1.41
8	15.95	1.97	15.57	2.21	1.50
All Colleges	15.04	0.30	13.63	0.62	1.03

Growth measures from item analyses.-- If we describe growth in knowledge of the subject matter measured by these tests as the differences between the deltas from the pre-test and post-test, then the difference between mean deltas will be a measure of the average growth for each college. To determine whether these differences are of any significance, we test the null hypothesis that these differences are not significantly greater than zero.

McNemar[1/] suggests the use of a critical ratio in situations such as this one. The critical ratio is defined by the formula $C.R. = \frac{D}{\sigma_{diff}}$. A critical ratio of 1.96 or more represents the five per cent level of confidence. This means that in five measurements out of every hundred such a difference

1/Quinn McNemar, Psychological Statistics, John Wiley and Sons, New York, 1949, pp. 66-67.

as this could exist only by chance. Similarly, the one per cent level tells us that there is only one chance in 100 such measurements that this difference could be attributed to chance. To reject the null hypothesis at the one per cent level of confidence, the critical ratio must be 2.576 or higher.

To determine if any of the colleges had average growth significantly different from the average growth of all the colleges, for Form E a difference of 2.65 or better would be significant at the five per cent level and a difference of 3.48 would be significant at the one per cent level. $\bar{\Delta}_1 - \bar{\Delta}_2$ represents this difference. Colleges 1 and 2 showed differences significant at the one per cent level. It can be concluded that there is only a one per cent chance of our being wrong when we state that these colleges showed an average growth in mastery of the material measured by Form E greater than the average growth for all the colleges.

For Form K, a difference between $\bar{\Delta}_1 - \bar{\Delta}_2$ of 1.67 or better was significant at the five per cent level and a difference of 2.19 was significant at the one per cent level. Colleges 1 and 2 showed differences from the average growth which were greater at the one per cent level.

Differences in average difficulty of items.-- The results of the pre-test with Form E showed that at the five per cent level the average difficulty of the items was significantly less for College 6 than the average difficulty of these items for all the colleges.

The pre-test results with Form K showed no significant differences between the average difficulty for any one college and the average difficulty for all the colleges.

The results of the post-test with Form E showed that the average difficulty of items was significantly less at the five per cent level for College 2 than the average difficulty of these items for all the colleges.

The post-test results from Form K showed that the average difficulty of the items was significantly greater at the five per cent level for College 8 than the average difficulty for all the colleges.

Item growth in each college.-- Growth has been described as the change in delta for an item from the pre-test to the post-test. If the data in Tables 4 through 19 are now examined on the basis of critical ratios, we find that there are differences in deltas which cannot be attributed to chance. Tables 22 through 29 show the items where losses in difficulty are significantly more than the average loss in difficulty for that college. These items indicate areas which apparently were either stressed in instruction or in which students learn easily.

Table 22. Items Which Show Growth Significantly Greater than the Average for College 1

Form E		Form K	
Items at Five Per Cent Level	Items at One Per Cent Level	Items at Five Per Cent Level	Items at One Per Cent Level
(1)	(2)	(3)	(4)
11	6	102	106
15	24	117	111
17	25	121	123
22	28	129	142
27	33	141	147
30	38	143	149
44	43	--	--

The items not included in this table are those on which it is assumed average improvement was made. Those listed showed better than average progress for six items in the area of mechanics, four in the area of light, six in the area of heat, eight in the area of magnetism and electricity, and two in the area of astronomy. Thus the students in this college showed better than average growth in most of the areas sampled by the test.

Table 23. Items Which Show Growth Significantly Greater than the Average for College 2

Form E		Form K	
Items at Five Per Cent Level	Items at One Per Cent Level	Items at Five Per Cent Level	Items at One Per Cent Level
(1)	(2)	(3)	(4)
4	3	101	104
9	7	102	105
10	17	123	106
14	21	124	107
18	22	125	109
19	36	127	113
23	38	129	117
24	45	132	136
25	46	138	137
30	48	149	139
31	--	--	144
34	--	--	--
35	--	--	--
39	--	--	--
49	--	--	--

The above table reveals a most interesting pattern of growth. There were 15 items on mechanics, 13 on electricity, and nine on astronomy that showed better than average growth. On the other hand, there were only six items on heat and three on light that fell into this category. It could be assumed that although greater emphasis was placed on the first three areas, all areas were well taught.

Table 24. Items Which Show Growth Significantly Greater than the Average for College 3

Form E		Form K	
Items at Five Per Cent Level	Items at One Per Cent Level	Items at Five Per Cent Level	Items at One Per Cent Level
(1)	(2)	(3)	(4)
26	6	114	113
33	11	134	121
--	38	--	136

The items listed above include four in the area of mechanics, two in astronomy, two in the area of heat, and one each in the areas of light and electricity.

Table 25. Items Which Show Growth Significantly Greater than the Average for College 4

Form E		Form K	
Items at Five Per Cent Level	Items at One Per Cent Level	Items at Five Per Cent Level	Items at One Per Cent Level
(1)	(2)	(3)	(4)
17	6	110	113
28	-	112	--
38	-	138	--
39	-	--	--

Five of the above items were concerned with mechanics, three with electricity, and one with heat.

Table 26. Items Which Show Growth Significantly Greater than the Average for College 5

Form E		Form K	
Items at Five Per Cent Level	Items at One Per Cent Level	Items at Five Per Cent Level	Items at One Per Cent Level
(1)	(2)	(3)	(4)
6	28	115	106
16	33	117	108
27	--	124	109
41	--	131	113
47	--	143	116
48	--	--	121
--	--	--	133*
--	--	--	139
--	--	--	140
--	--	--	141
--	--	--	145
--	--	--	149

* This item showed an increase in difficulty.

The above table reveals significant gains on nine items on electricity, seven on mechanics, six on heat, and two on light.

A gain significantly lower than the average was shown on item number 133 which deals with knowledge of theories of cosmogeny. This distribution could be considered a clue to the areas of emphasis in this college.

Table 27. Items Which Show Growth Significantly Greater than the Average for College 6

Form E		Form K	
Items at Five Per Cent Level	Items at One Per Cent Level	Items at Five Per Cent Level	Items at One Per Cent Level
(1)	(2)	(3)	(4)
26	27	111	106
43	38	141	122
--	--	143	--
--	--	147*	--

* This item showed an increase in difficulty.

Three of these items were on electricity and two each were concerned with mechanics, heat, and light. One item on electricity showed a significant increase in difficulty.

Table 28. Items Which Show Growth Significantly Greater than the Average for College 7

Form E		Form K	
Items at Five Per Cent Level	Items at One Per Cent Level	Items at Five Per Cent Level	Items at One Per Cent Level
(1)	(2)	(3)	(4)
17	38	106	121
33	43	117	123
48	--	146	134
--	--	--	141

Six of these items were concerned with electricity, three with heat, two with mechanics, and one with astronomy.

Table 29. Items Which Show Growth Significantly Greater than the Average for College 8

Form E		Form K	
Items at Five Per Cent Level	Items at One Per Cent Level	Items at Five Per Cent Level	Items at One Per Cent Level
(1)	(2)	(3)	(4)
--	6	117	--
--	24	127	--
--	38	149	--

Two each of these items were concerned with areas of light and electricity respectively. The other two sampled areas of mechanics and heat.

Table 30. Frequency Distribution of Items Which Indicated Growth in Three or More Colleges

Item	Frequency	Item	Frequency
(1)	(2)	(1)	(2)
6	5	106	5
17	4	113	4
24	3	117	5
27	3	121	4
28	3	123	3
33	4	141	4
38	7	143	3
43	3	149	4
48	3	--	-

Table 30 gives the frequency distribution of the items from the previous eight tables which show significant growth in three or more colleges. These items require a knowledge of the following facts, concepts, or principles:

The concept that all measurement contains error

The principle of the inverse square law as it applies to gravity and static electricity, but not as it applies to magnetism

The concept of mechanical advantage of machines

The concept of kinetic energy

The concept of expansion with heat

The use of the concept of unequal expansion in the operation of heat instruments

The principle of construction of thermometer scales

The concept of heat transmission by convection

The fact that the expansion of water on heating is unorthodox

The concept of the photo-chemical action on photographic film

The concept of the selective transmission of light

The concept that electric charges involve a gain or a loss of electrons

The concept of an electro-magnetic field

The concept of the factors which affect the resistance of a current-carrying wire

The concept of the rectification of alternating current

The historical fact that Oersted first observed the magnetic field around a current-carrying wire.

Table 31. Frequency Distribution of Items Which Were Significantly More Difficult at the Five Per Cent Level than the Average Difficulty in at Least Three Colleges.

Item	Frequency
(1)	(2)
5	6
44	4
150	6

Location of difficult items.-- An examination of the above table reveals this information:

Item 5 requires knowledge of the fact that the kilogram is the metric standard of weight. Eighty-seven per cent of those answering in these colleges chose gram rather than kilogram, an indication that the students were familiar with the metric system but had not learned precisely what the standards are.

Item 44 requires a knowledge of Ohm's law applied to alternating currents. It is quite probable that this was not learned in four of the eight colleges.

Item 150 is obviously a most difficult question. The directions for the test tell the student to choose the best answer. The correct answer is 26.2; the choice closest to it is 22. The question requires a student to follow directions to the letter, to be able to compute the total resistance in a parallel circuit, and to use Ohm's law. This is probably a poor question and should be revised.

<u>Results of the pre-test</u>.-- After the tests were scored, the sums of the scores and the sums of their squares were obtained for each college, for males, for females, for the total population, and for a restricted group which was made up of colleges 1, 2, 3, 4, 5, and 8. The means and standard deviations were calculated--the means by the usual method of dividing the sum of scores by the number of cases, and the standard deviations with the formula given by McNemar.[1/]

$$S.D. = \frac{1}{N}\sqrt{N\Sigma X^2 - (\Sigma X)^2}$$

These statistics are listed in Table 32.

Table 32. Distribution Statistics from Pre-test Raw Scores

Group	N	$\overline{E}_1$	S.D.	$\overline{K}_1$	S.D.	$\overline{T}$	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
College 1	77	14.41	4.41	12.06	4.09	26.44	7.92
College 2	47	16.21	9.10	14.15	4.19	30.36	8.06
College 3	110	15.57	4.12	12.52	3.88	28.09	7.10
College 4	73	15.74	3.88	14.10	3.89	29.84	6.83
College 5	87	16.97	4.18	14.92	4.09	31.88	7.13
College 6	139	18.96	4.27	14.68	6.09	33.59	7.50
College 7	243	16.40	4.13	12.58	4.36	28.98	5.77
College 8	108	15.35	3.87	12.23	3.88	26.61	6.56
Restricted	502	15.50	4.18	13.22	4.07	29.32	4.18
Male	215	17.66	4.43	14.89	4.76	32.55	6.14
Female	669	16.04	3.93	12.75	3.56	28.79	4.74
All Groups	884	16.43	4.13	13.27	3.99	29.68	6.99

In the above table, N represents the number of students; $\overline{E}_1$, the mean of Form E; S.D., the standard deviation for the distribution whose mean is to the left of it; $\overline{K}_1$, the mean of

1/Quinn McNemar, <u>op. cit</u>., p. 25.

Form K; and $\overline{T}$, the mean for the total scores from both forms.

Results of the post-test.-- Table 33 lists the means and standard deviations calculated from the post-test raw scores. These are identified in a manner similar to that described for Table 32.

Table 33. Distribution Statistics from Post-test Raw Scores

Group	N	$\overline{E}_1$	S.D.	$\overline{K}_1$	S.D.	$\overline{T}$	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
College 1	77	25.47	7.86	23.35	7.18	48.82	17.14
College 2	47	29.64	5.70	27.91	6.26	57.55	10.92
College 3	110	21.71	5.38	18.74	5.71	40.45	10.16
College 4	73	20.67	9.11	18.25	6.90	38.92	11.44
College 5	87	21.90	5.88	21.17	6.08	43.07	10.77
College 6	139	21.07	4.68	18.03	8.37	39.09	8.25
College 7	243	19.52	7.44	17.86	6.40	37.38	5.77
College 8	108	18.90	4.00	14.49	4.29	40.34	7.35
Restricted	502	22.35	6.75	19.78	6.51	42.13	12.80
Male	215	22.93	7.01	20.40	7.09	43.32	13.11
Female	669	20.87	6.18	18.51	6.00	39.37	8.90
All Groups	884	21.37	6.46	18.96	6.37	40.34	11.56

Stanine scores.-- The students' raw scores were converted into stanines which were assigned from a stanine chart made available by Dr. Walter N. Durost. These scores were based on the distribution of raw scores for the total population.

Table 34 lists the mean stanine scores for each of the above mentioned groups. The mean stanines were calculated for each form of the test from the pre-test and the post-test.

Table 34. Stanine Scores

Group	Pre-test Form			Post-test Form		
	E	K	Total	E	K	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)
College 1	3.96	4.62	4.08	6.14	6.25	6.31
College 2	4.74	5.49	5.17	7.32	7.32	7.49
College 3	4.60	4.95	4.64	5.35	4.91	5.16
College 4	4.58	5.62	5.07	4.81	4.73	4.67
College 5	5.14	5.91	5.64	5.20	5.67	5.45
College 6	6.05	5.86	6.09	5.04	4.65	4.86
College 7	4.92	4.93	4.86	4.49	4.59	4.53
College 8	4.38	4.70	4.40	4.32	3.53	3.72
Restricted	4.56	5.16	4.79	5.33	5.15	5.23
Male	5.41	5.87	5.66	5.52	5.36	5.45
Female	4.72	4.99	4.81	4.90	4.78	4.82
All Groups	4.91	5.21	5.01	5.05	4.92	4.98

Indication of rate of growth from mean stanine scores.--A measure of relative growth for each group was determined by finding the ratio of the post-test mean stanine score to the pre-test mean stanine score, which gave the relative position of that group to the total population. The ratio obtained indicated rate of growth. A ratio of 1.00 indicates average growth for the population. A ratio of more than 1.00 shows growth greater than the average, and a ratio of less than 1.00, growth less than average.

Table 35 lists the obtained ratios.

Table 35. Ratio of Post-test Stanines to Pre-test Stanines

Group (1)	Form E (2)	Form K (3)	Totals (4)
College 1	1.55	1.35	1.55
College 2	1.54	1.33	1.45
College 3	1.16	.99	1.11
College 4	1.05	.84	.97
College 5	1.01	.96	.97
College 6	.83	.79	.80
College 7	.91	.93	.93
College 8	.99	.75	.85
Restricted	1.17	1.00	1.09
Male	1.02	.91	.96
Female	1.04	.96	1.00
All Groups	1.03	.94	.99

Indications of normality.-- The stanine chart assumes a normal distribution of raw scores for the population. The mean stanine score should be 5.00 and the mean growth rate previously mentioned should be 1.00. Tables 34 and 35 show departures from normality for the total population (All Groups) which are not statistically significant. It can be concluded that all the scores obtained for the population were normally distributed.

Product-moment correlations.-- The product-moment correlations of Form E with Form K were calculated for each of the groups previously described. These correlations are a measure of the reliability of the test. In addition, the total pre-test score was correlated with the total post-test score for each group. This latter coefficient appears to be a spurious test - retest correlation with the testing in October and the retesting in May. However, it should be considered as in indication of homogeneity of growth for the groups measured. If the post-test totals correlate highly with the pre-test totals, a homogeneous growth rate is indicated for the students in that group. On the other hand, if this coefficient is low, the growth for the students in the group is not homogeneous. The product-moment correlations were calculated with the formula suggested by McNemar.[1/]

$$r = \frac{N\Sigma XY - \Sigma X\Sigma Y}{\sqrt{N\Sigma X^2 - (\Sigma X)^2}\sqrt{N\Sigma Y^2 - (\Sigma Y)^2}}$$

Table 36 gives these correlation coefficients for each group. Columns 2 and 3 list reliability coefficients and column 4 is the list of coefficients which may be considered as indices of homogeneity. The coefficients for totals for males, for females, and for the population (All Groups) show there is little homogeneity in growth. The restricted group shows a more homogeneous growth.

It should be noted that the more homogeneous restricted group shows significantly higher coefficients than does the population as a whole.

1/Quinn McNemar, op. cit., p. 96.

Table 36. Product-Moment Correlations Obtained from Raw Scores on Pre-test and Post-test

Group	E with K		$E_1 + K_1$ with $E_2 + K_2$
	rE_1K_1	rE_2K_2	rt_1t_2
(1)	(2)	(3)	(4)
College 1	.51	.71	.40
College 2	.34	.67	.65
College 3	.56	.69	.59
College 4	.53	.60	.75
College 5	.46	.61	.69
College 6	.34	.33	.67
College 7	.16	.45	.42
College 8	.43	.67	.80
Restricted	.65	.78	.51
Male	.56	.72	.30
Female	.35	.58	.34
All Groups	.44	.63	.33

Analyses of variance.-- Further study of the similarities and differences existing among the various colleges indicated an analysis of variance. The technique used is described by McNemar.[1/] Estimates were calculated from the following formula:

$$\sum_r \sum (X - \bar{X}_r)^2 = \sum\sum X^2 - \sum_r \frac{(\sum X)^2}{m_r}$$

which gives the within groups sum of squares. The second term requires that for each group the square of the sum of its scores must first be divided by its m, the number of cases in the group. Then the separate quotients were summed.

1/Quinn McNemar, op. cit., pp. 241-248.

Between groups sum of squares were calculated with the formula

$$\sum^{r} m_r (\bar{X}_r - \bar{X})^2 = \sum^{r} \frac{(\sum X)^2}{m_r} - \frac{(\sum\sum X)^2}{N}$$

The first term was obtained by dividing the squared sum for each group by m, the number in the group, and summing the quotients.

The total sum of squares was obtained from the formula

$$\sum\sum(X - \bar{X})^2 = \sum\sum X^2 - \frac{(\sum\sum X)^2}{N}$$

The total sum of squares provides a check on calculation. The within sum of squares and the between sum of squares should total to it.

The within and between sums of squares were respectively divided by the appropriate degrees of freedom to obtain the desired variances. The between groups degrees of freedom are the number of groups minus one; the within groups degrees of freedom are the difference between the number of cases in the population and the number of groups.

These data and the variance estimates are shown in Tables 37 to 44.

Table 37. Estimates of Variance for Form E Pre-test Scores for All Colleges

Source	Sum of Squares	Number of Degrees of Freedom	Variance Estimate
(1)	(2)	(3)	(4)
Between	7,312	7	1,044.57
Within	228,884	876	261.28
Total	236,196	883	

The variance ratio, F, was obtained by dividing the between groups variance estimate by the within groups variance estimate. The F obtained from the above table was 4.00. Reference to a table of F's, entered with the appropriate degrees of freedom, tells whether this ratio is larger than expected on the basis of chance. The F obtained from these variances shows that there were significant differences among the means of the groups measured by the test. The differences were significant at the 0.001 level of confidence.

Table 38. Estimates of Variance for Form K Pre-test Scores for All Colleges

Source	Sum of Squares	Number of Degrees of Freedom	Variance Estimate
(1)	(2)	(3)	(4)
Between	10,986	7	1,569.43
Within	3,116	876	3.56
Total	14,102	883	

The F ratio of 4,408.5 shows that on Form K of the pre-test the groups' means differed significantly among themselves at the 0.0001 level of confidence.

Table 39. Estimates of Variance for Form E Post-test Scores for All Colleges

Source	Sum of Squares	Number of Degrees of Freedom	Variance Estimate
(1)	(2)	(3)	(4)
Between	3,979	7	568.43
Within	32,892	876	37.55
Total	36,871	883	

At the 0.001 level, it can be stated that with an F of 15.14 the means of the groups making up this population differ significantly from one another on post-test Form E.

Table 40. Estimates of Variance for Form K Post-test Scores for All Colleges

Source	Sum of Squares	Number of Degrees of Freedom	Variance Estimate
(1)	(2)	(3)	(4)
Between	8,075	7	1,153.57
Within	27,758	876	31.69
Total	35,833	883	

With an F of 36.40 which is significant at less than the 0.001 level, it can be stated that the means of the colleges obtained from post-test Form K differ markedly among themselves.

Table 41. Estimates of Variance for Form E Pre-test Scores for Male and Female

Source	Sum of Squares	Number of Degrees of Freedom	Variance Estimate
(1)	(2)	(3)	(4)
Between	543	1	543.00
Within	14,550	882	16.50
Total	15,093	883	

The variance ratio F of 32.91 obtained from the scores of pre-test Form E indicated that the average score of the male students is significantly different from the average score of the female students. Reference to Table 32, page 72, shows that the average male score is higher than the average female score.

Table 42. Estimates of Variance for Form K Pre-test Scores for Male and Female

Source	Sum of Squares	Number of Degrees of Freedom	Variance Estimate
(1)	(2)	(3)	(4)
Between	757	1	757.00
Within	13,345	882	15.13
Total	14,102	883	

The F of 50.03 obtained from these variances is significant at the 0.001 level. Reference to Table 32, page 72, indicates that the average male student scored significantly higher on this test than did the average female.

Table 43. Estimates of Variance for Form E Post-test Scores for Male and Female

Source	Sum of Squares	Number of Degrees of Freedom	Variance Estimate
(1)	(2)	(3)	(4)
Between	10,721	1	10,721.00
Within	36,150	882	40.99
Total	46,871	883	

It can be concluded that with a variance ratio of 261.85 there are significant differences at the 0.001 level or better between their means. Reference to Table 33, page 73, shows that the average male student had a higher score on post-test Form E than did the average female student.

Table 44. Estimates of Variance for Form K Post-test Scores for Male and Female

Source	Sum of Squares	Number of Degrees of Freedom	Variance Estimate
(1)	(2)	(3)	(4)
Between	907	1	907.00
Within	34,926	883	39.55
Total	35,833	884	

An F of 29.93 which indicates significance at the 0.001 level means that it can be stated with a high degree of confidence that there is a difference between these two means. Table 33, page 73, shows that the male students achieved a higher average score than did the female students on this test.

The fact that variance ratios indicate differences in group means suggested the use of the standard error for the difference of means. The standard error was computed in accordance with the so-called short formula [1/]

$$\sigma(M_1 - M_2) = \sqrt{\sigma^2_{M_1} + \sigma^2_{M_2}}$$

which was used since the colleges tested in this study were not matched. The appropriate within groups variance estimate was used in the usual formula for variance of the mean. The standard errors for the mean differences found are shown in Table 45.

Table 45. Standard Errors of Mean Differences of Test Scores

Test	Standard Error of Mean Difference
(1)	(2)
Pre-test E	0.77
Pre-test K	0.09
Post-test E	0.29
Post-test K	0.27

1/E. F. Lindquist, A First Course in Statistics, Houghton Mifflin Co., Cambridge, Mass., 1942, p. 130.

A critical ratio of 1.96 is significant at the 0.05 level and one of 2.576 at the 0.01 level. Table 46 shows the differences which were found to be significant.

Table 46. Significant Differences from Grand Mean of Colleges

Test (1)	0.05 Level (2)	0.01 Level (3)
Pre-test E	1.51	1.98
Pre-test K	0.18	0.23
Post-test E	0.58	0.75
Post-test K	0.53	0.70

It was not necessary to use the standard error of the mean difference to determine whether the mean of the male students differed from the mean of the female students. The variance ratio, F, for these two groups showed that male performance on all tests was significantly higher than the average performance for females.

An examination of Tables 32 and 33, on pages 72 and 73, reveals differences between means which are greater than those listed above. Table 47 indicates the colleges whose mean scores were significantly more or less than the mean of the population on each of the tests. A comparison of the relative position of a college on pre-test and post-test serves as a check on the average growth rates previously mentioned. It is interesting to note that no college is average, above average, or below average on all four tests.

Table 47. Colleges Whose Means Were Significantly Different at the 0.01 Level from Grand Means

College	Pre-test Form E		Pre-test Form K		Post-test Form E		Post-test Form K	
	More	Less	More	Less	More	Less	More	Less
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1		X		X	X		X	
2			X		X		X	
3				X				
4			X			X*		X
5			X				X	
6	X		X					X
7				X		X		X
8			X			X		X

* 0.05 level

Table 47 shows that in knowledge of subject matter measured by pre-test Form E only two colleges differed from the average performance of all colleges. It can be inferred that the students in College 6 began the course with a richer than average background knowledge and that the students in College 1 began the course with a poorer than average background knowledge. The students in College 6 were also better than average on pre-test Form K, while the students in College 1 were below average on this test. However, on the post-test, College 6 was below average while College 1 was above average. Apparently the students of College 1 showed more growth in the areas measured by this test than did those of College 6.

It might be argued that the average of College 6 was so high at the beginning that it was impossible for it to maintain its better than average position. An examination of the test scores does not support this hypothesis. Further, an admission from the science faculty of this college that it did not follow the outline closely enough suggests that its students did not have the opportunity to learn all the material measured by the test. This is a more logical explanation of the drop in relative standing.

Comparisons of positions of the means of the colleges as shown in the previous table and further comparisons of their relative growth rates could be used to indicate how closely the accepted course outline was followed. However, such a use is not considered within the scope of this study.

Summary.-- Two forms of a test of physical science, E and K, were constructed by the selection of appropriate items from a MASTER LIST. This list was subjected to item analysis and each of the items appearing in Forms E and K had a minimum discrimination index of 0.30. The two test forms were composed of items whose difficulties had comparable means and standard deviations.

The two forms were administered to all available elementary education majors in eight State Teachers Colleges both as a pre-test and a post-test at the beginning and the end of the 1957-1958 academic year. Analyses of the items from the results of these tests showed that there was significant growth in certain areas of subject matter presumably sampled by the test items. The analyses also showed that the rates of growth in certain colleges were significantly higher than the average population growth. One college showed a rate of growth significantly lower than average. The difference in growth rates is a possible indication that the program may have been followed more closely in some of the colleges than in others.

Analyses of the variances of test scores showed that the means of the colleges on the various measures differed significantly among themselves. Colleges were identified whose means were significantly greater or less than the population mean. The distribution of stanines indicated that the test scores for the population were normally distributed.

Growth rate was also shown for each group by the use of a ratio of post-test to pre-test mean stanine. These growth rates compared favorably with those obtained from delta statistics of item analyses. The suggestion is made that the use of stanine ratios will simplify the identification of relative rates of growth for groups in a population.

The product-moment correlations between the two forms of the test were 0.44 and 0.63, a low reliability for predicting the score of a student on Form K from his score on Form E. It is acceptable, however, for use in discussing the average performance of groups of students in this particular college population.

Instructors in Colleges 6 and 7 admitted that they did not follow the outline of the course of study, which was one of the conditions on which this study was based. For this reason, a "restricted" group which does not include Colleges 6 and 7 was established. The reliability of the pre-test for this group was 0.65 and for the post-test, 0.78. Apparently, large errors affecting correlation were introduced in Colleges 6 and 7.

A correlation coefficient between pre-test total and post-test total was used as an index of homogeneity of growth. The amount of homogeneity was small for the population and consistently higher for each of the colleges. This conclusion agrees with results obtained from analyses of variance.

The performance of the average male student was significantly higher than that of the average female student.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to construct a test of physical science designed to measure mastery of facts, concepts, and principles. The study showed how such a test could be used for various groups to show areas and rates of growth in the mastery of this subject matter.

The test was constructed by using item analyses to select appropriate items from a pool of items. It was administered to all elementary education majors who were taking the course in physical science in eight teachers colleges.

Validity.-- No attempt was made to establish validity in terms of correlations with quantitative data such as grades or scores on other tests. In addition to mastery of facts, concepts, and principles, other factors are usually considered in assigning student grades. Thus the correlation of the scores from this test with such grades would be relatively devoid of meaning. There is no other test available which is designed to measure the specified outcomes of this particular course. Hence it was impossible to establish this correlation.

A negative approach to validity was used when it was indicated that the correlation was low between the MASTER LIST scores of the students in the criterion group and their scores on other tests. These "other tests" were the Otis Quick Scoring Test of Mental Ability; the test of the Ability to do quantitative Thinking of the Iowa Tests of Educational Development; and the sub-tests on Vocabulary, Speed of Comprehension, and Mechanics of Expression of the Cooperative English Test. The low correlations made it possible to assume that the items on the MASTER LIST measured something other than the factors measured by the above-mentioned tests.

Validity from jury ratings.-- A more positive approach to validity was the use of jury ratings. A jury composed of an instructor from each of the teachers colleges rated the items on the MASTER LIST on a five point scale. Five, four, and three on this scale indicated degrees of acceptance of the items as an appropriate measure of some area of course content. Ratings of two and one indicated degrees of doubt as to the appropriateness of the items. The ratings of the jurors were averaged. A mean jury rating of 3.00 or better meant that the majority of the jurors considered that item a valid measure of some area of course content. The fact that no item was used on the final forms of the test with an average jury rating of less than 3.00, and that most items had ratings considerably higher than this, established a measure of consumer validity for the test.

Construct validity.-- One of the statistics obtained from the analysis of the MASTER LIST items was r, the index of discrimination between those who scored high and those who scored low on the MASTER LIST as a whole. The use of items with an r of 0.30 or better insured a measure of construct validity.

Additional insurance of construct validity was the fact that the final forms were prepared so as to have comparable mean difficulties and standard deviations.

Reliability.-- The coefficients of reliability of 0.44 for the pre-test and 0.63 for the post-test were lower than hoped for. These can be considered, however, as minimal reliabilities. The elimination of Colleges 6 and 7 from the population raised the coefficients to 0.65 and 0.78 respectively. These two colleges may be thus eliminated because they did not follow all the conditions agreed upon for testing.

If the two forms of the test are considered as matched halves and the Spearman-Brown formula is applied, the coefficients become respectively 0.79 and 0.87. This approaches the realm of respectability.

Guilford[1/] says,

> "Another idea of reliability conceives of the 'true scores' for a group of individuals and asks how closely the obtained scores correlate with the true scores...... true scores are defined as those the testee would receive if the test were perfectly reliable...... and this correlation is definitely related to the correlation between the forms or halves by the equation,
>
> $$r_{1\infty} = \sqrt{r_{11}}$$
>
> where r_1 is the correlation between the obtained scores and the true scores."

1/J. P. Guilford, *Fundamental Statistics in Psychology and Education*, McGraw-Hill Book Co., Inc., New York, 1942, p. 278.

Viewing reliability in this light, the correlations become 0.66 and 0.80 for all eight colleges and 0.80 and 0.88 for the restricted group. The near equality of these latter and those prophecied by the Spearman-Brown formula leads to the speculation that these are the maximal reliabilities obtainable from this population with this test.

This speculation is borne out by the author's knowledge of the teachers colleges' population in this sample. Very few students gain admission to the colleges whose average of high school grades is below the seventieth percentile. Physical science is offered in the second year. Most students with very poor study habits fail the first year and are not allowed to continue. On the other hand, the exceptionally able high school students usually go to the liberal arts colleges and to the universities. Thus the population tends to be relatively homogeneous and places a limit on the variance of scores and consequently on reliability.

Suggestions for improving reliability.-- Error was introduced by several factors. The test contained some items of such high difficulty that these tended to reduce reliability. The average number of correct responses to both post-test forms was 40.34 per cent. If the more difficult items were removed and replaced with items of from 50 to 60 per cent difficulty, the coefficients would show significant increase.

It was reported that the time alloted for the test was very generous and that all students had sufficient time to complete a test half again as long. The implication is that both forms should be lengthened to 75 items each. If this lengthening were to be done in terms of items of average difficulty, further increases in reliability should result.

Measurement of growth.-- In the opinion of the author, the most useful outcomes of this study were its measures of growth. Absolute and relative growth rates were indicated by the differences in deltas (indices of difficulty) and by the ratio of mean stanine scores. The stanine ratios lend themselves to less complicated statistical procedures than do the item analyses. Such ratios present a relatively easy way of determining both individual and group growth rates and as such are a most useful tool in appraising the outcomes of instruction within the frame of reference of the present study. The ratios in both their present and projected uses would serve as a basis for realistic revision of the present course. Testing over a period of two or more years with an improved test would provide growth rates indicating areas where students in this type of course can show satisfactory progress and underscoring other areas which are perhaps too advanced or difficult.

Major findings of this study.-- In the light of all available data the major findings of this study are: that a useful test of physical science as it is taught in the State Teachers Colleges of Massachusetts was constructed; that the best use of this test is the measurement of group knowledge of facts, concepts, and principles; that item analyses can be used to indicate group growth on specific items and relative growth with respect to other groups; that the stanine ratio can be used to show group growth rates.

Limitations of the study.-- The most desirable way in which this test could have been administered would have been to have the same person administer it in all the colleges. Limitations of time and distance made this impossible. It would be naive to assume that all instructors administering this test had the same interest in its success as the author. Consequently, there were cases of careless administration. In two of the colleges there were over 200 improperly written answer sheets. This carelessness found in these two colleges and probably existing in lesser degree in the others undoubtedly lowered the reliability.

The fact that the directions practically encouraged guessing also tended to reduce reliability, particularly on the pretest.

The limiting of the measurement to the mastery of knowledge of facts, concepts, and principles, narrowed the scope of the test to the point where it can only be claimed that it is a necessary first step in the evaluation of a new course of study. This limitation was imposed on the test by the physical science course outline whose outcomes it attempted to measure. The outline has a very few generalized objectives and its specific objectives consist of a mere listing of topics. Thus the test items, no matter how carefully constructed and selected, reflected to a large extent the personal bias of the author. The outline precluded the measurement of the "higher" outcomes of science instruction by its lack of specificity. It would have been imprudent to have attempted measurement of such outcomes with no guarantee that they were included in the outcomes of instruction in the various colleges.

Recommendations for further study.-- On April 3, 1959, at the State Teachers College at Bridgewater, a summary of this study was read before the assembled science instructors of all the colleges. The consensus was that this study should be included in the broad area of a revision and expansion of the present course outline. It was voted to request the Director of the Teachers Colleges to appoint a faculty committee and to budget funds sufficient to enable the committee to succeed in its requested project. The task of revising and enlarging the test would also be included in this committee's work. The enlargement could be done with an eye to establishing a worthwhile state wide testing program from which valuable data for the improvement of instruction could be obtained.

There are many state systems of teachers colleges and regional associations which accredit them. Well-designed programs like this one for these systems would go far in enabling these systems and associations to evaluate the outcomes of instruction. The advantage of having the impetus for such evaluation come from within rather than from outside of a system is obvious. Such programs of testing are practically non-existent and thus offer a fertile field not only for the construction of science tests but also for the construction of tests in many other fields of learning.

Within the narrower scope of the education of elementary school teachers, a study such as this suggests many further investigations using this test. The perennial argument as to the advantage (or lack of it) of laboratory work over the lecture-demonstration method can be re-examined in the light of data obtained from this test or one similar to it. It is interesting to note that both Colleges 1 and 2, which showed the greatest growth, provided supervised individual laboratory for their students while the other colleges did not.

In the elementary school of today, more emphasis is placed on the learning of science than ever before. Considerable research has been done on the grade placement of science principles and on the pupils' ability to master them. However, no study has ever been made of the ability of the average elementary school teacher to learn facts and understand concepts and principles she is being asked to teach. Perhaps future designers of elementary science curricula should investigate the teacher as well as the learner in their planning. Such investigation may indicate a need for specially gifted and trained teachers for the especially gifted pupil in the science areas. This approach to the teaching of science in the elementary grades might be one of the ways in which we can discover, develop and conserve our needed science brain power.

The methodology employed in this study, while primarily statistical, has far-reaching philosophical and psychological connotations. A customary approach to testing is the listing of specific outcomes of instruction followed by the construction and validation of a test purporting to measure these outcomes. It can be argued that this traditional approach tends to freeze a curriculum into a predetermined pattern and makes no allowance for adaptation or change. A common complaint is that the desire to have a school "do well" on the test results in a stultifying of instruction. Experimental teaching methods, changes in emphasis, and introduction of new material are inhibited by the need of meeting requirements set forth in the original objectives and stringently measured by its accompanying testing program.

The present study was forced by the necessities of the frame of reference to follow a different pattern. The course outline whose outcomes the test attempts to measure had very poorly defined specific objectives. Consequently, the items of the test were designed to sample wide areas of subject matter within a limited cognitive scope. The contribution of this study is its synthesis of several accepted methods of analysis in such a way as to show how the results of such a test can be used as a guide to the empirical determination of specific course objectives.

The present study makes no pretense of being complete in the sense of having located all the desired course outcomes. However, it can be claimed that if its methods are followed, with more instructors participating and with increasingly wider coverage of types of learning outcomes, a store of information useful for improving all phases of instruction will result.

The unique contribution of this study is the presumably novel use of the index of difficulty, delta. The usual use of this statistic is the comparing of item difficulties on two forms of the same test or of two different tests. In this study the differences between pre-test and post-test deltas were treated as linear statistics to indicate a decrease in difficulty and consequently an increase in the mastery of the subject matter measured by the items. This use can be recommended as leading to many worthwhile studies in the area of growth.

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APPENDIX A

MASTER LIST OF ITEMS

* Item included in final test.

1. The amount of space an object occupies is its: (1) mass, (2) weight, (3) volume, (4) density, (5) specific gravity.

*2. A milli-ammeter would read: (6) thousandths of an amp, (7) thousands of amps, (8) hundredths of an amp, (9) millionths of an amp, (10) millions of amps.

*3. The smallest scale markings on a meter stick are: (1) microns, (2) centimeters, (3) kilometers, (4) millimeters, (5) decimeters.

*4. On the vernier caliper the smallest marking on the vernier scale is equal to: (6) a centimeter, (7) a millimeter, (8) micron, (9) a tenth of a centimeter, (10) a tenth of a millimeter.

*5. Which of the following <u>is not</u> a property possessed by all matter: (1) density, (2) elasticity, (3) inertia, (4) volume, (5) mass.

*6. The metric standard of weight is the: (6) gram, (7) kilogram, (8) erg, (9) meter, (10) liter.

*7. To change meters to centimeters, we: (1) divide by 10, (2) multiply by 100, (3) divide by 100, (4) multiply by 1000, (5) divide by 1000.

8. If a spring stretches one inch when a weight of two pounds is attached to it, according to Hooke's law how far should it stretch if a five pound weight is attached to it: (6) 10 in., (7) 1/5 in., (8) 5/2 in., (9) 2/5 in., (10) 5 in.

9. According to the accepted theory of matter, molecules <u>are not</u> considered: (1) to be separated by relatively large distances, (2) to be in motion, (3) to be at rest in solids, (4) to increase in motion with an increase in temperature, (5) to exert various forces on each other.

10. The expression describing the amount of matter in a body is: (6) weight, (7) mass, (8) volume, (9) density, (10) specific gravity.

11. The ratio of the weight of a substance to the weight of an equal volume of water is known as its: (1) mass, (2) density, (3) volume, (4) efficiency, (5) specific gravity.

12. If the specific gravity of a substance is 13.6, which of the following <u>is not</u> true of the substance: (6) it has a density of 13.6 grams per cubic centimeter, (7) it is heavier than an equal volume of water, (8) 1 cubic centimeter of this substance would weigh 3.6 grams, (9) it would sink in water, (10) it would float in molten iron.

13. The instrument commonly used to measure the specific gravity of liquids is the: (1) barometer, (2) sinker, (3) beam balance, (4) hygrometer, (5) hydrometer.

14. Which of the following is an expression of Boyle's Law: (6) $PV = T$, (7) $PV = K$, (8) $P/V = K$, (9) $PT = V$, (10) $PV/T = K$.

15. Two weights, one of 10 gr. and the other of 5 gr., are suspended at opposite sides of a bar supported at its center. If the 5 gr. weight is 4 cm. from the center, how far from the center will the 10 gr. weight be: (1) 4, (2) 2, (3) 10, (4) 20, (5) 40.

16. The point at which all the weight of a body is effectively concentrated is called its: (6) midpoint, (7) fulcrum, (8) component, (9) torque, (10) center of gravity.

17. If a 10 gr. force and a 50 gr. force are acting from the same point in the same direction, which of the following best represent what is happening: (1) a 60 gr. resultant, (2) a 40 gr. resultant, (3) an equilibrant of 40 gr., (4) an equilibrant of 60 gr., (5) a vector 60 cm. long.

*18. A single force which balances several non-parallel forces is called: (6) a vector, (7) magnitude, (8) diagonal, (9) resultant, (10) equilibrant.

19. An auto starts from rest. At the end of the first second its speed is 8 ft./sec. At the end of the second second its speed is 16 ft./sec. Its acceleration is: 8 ft./sec/sec, (2) 16 ft./sec/sec, (3) a ft/sec/sec, (4) 8 ft./sec, (5) 16 ft./sec.

20. Which of the following <u>is not</u> true of a pendulum: (6) to complete a period, it must return to its starting position, (7) the time for one complete vibration is its period, (8) the period is independent of the weight, (9) the period is independent of the length, (10) the period is inversely proportional to the frequency.

21. The ability to do work is called: (1) inertia, (2) momentum, (3) force, (4) energy, (5) work.

22. Which of the following is not an example of potential energy: (6) a girl skating, (7) a taut bow, (8) a wound up spring, (9) a stick of dynamite, (10) a slice of bread.

*23. Machines are not used to: (1) convert one kind of energy to another, (2) multiply force, (3) increase speed, (4) decrease resistance, (5) change the direction of a force.

*24. A pulley system has an ideal M.A. of 4. Theoretically, to raise a 500 gr. weight it requires: (6) 125 gr., (7) 200 gr., (8) 2000 gr., (9) can't tell unless distance is given, (10) can't tell unless we are told how many pulleys in the system.

25. The ratio of the force necessary to draw one object over the surface of a second to the perpendicular force between the surfaces is: (1) effort, (2) resistance, (3) M.A., (4) friction, (5) coefficient of friction.

26. The rowing oar in a boat best illustrates what type of simple machine: (6) lever, (7) wheel and axle, (8) pulley, (9) wedge, (10) inclined plane.

27. One of the following does not affect the efficiency of a machine: (1) the ratio of resistance to effort, (2) friction, (3) coefficient of friction, (4) Joules, (5) ratio of M.A. to Ideal M.A.

*28. 0^oF is approximately equal to: (6) $32^oC.$, (7) $-18^oC.$, (8) $273^oK.$, (9) $273^oC.$, (10) $0^oC.$

29. The amount of linear expansion of an object is independent of: (1) its coef. of expansion, (2) composition of the substance, (3) change in temperature, (4) length, (5) volume.

*30. Water reaches its maximum density at: (6) 0^o, (7) $4^oC.$, (8) $100^oC.$, (9) as ice, (10) as steam.

*31. Water in a kettle is heated principally by: (1) conduction, (2) convection, (3) radiation, (4) agitation, (5) thermodynamics.

32. White clothing keeps people cooler in the tropics chiefly because of: (6) convection, (7) conduction, (8) radiation, (9) insulation, (10) it is made of cotton.

*33. Most thermometers operate on the principle of: (1) radiation, (2) transmission, (3) conversion, (4) expansion, (5) conduction.

34. Your wet hand will freeze quicker to a metal doorknob than to the wooden door because the knob is: (6) colder, (7) a good conductor, (8) a poor conductor, (9) round, (10) metal.

35. On a warm day a gallon of gasoline: (1) weighs more than on a cold day, (2) weighs less than on a cold day, (3) ways the same as on a cold day, (4) has a smaller volume than on a cold day, (5) has a larger volume than on a cold day.

36. The process of measuring an object is basically one of: (6) finding its length, (7) weighing it, (8) choosing an appropriate scale, (9) comparing it with another measure, (10) being exact.

37. Errors of measurement are primarily due to: (1) carelessness, (2) inability to do arithmetic, (3) inadequacy to measuring instruments, (4) temperature changes, (5) poor scale construction.

*38. Metric units are preferred to English units because: (6) they make computation easier, (7) they tend to be more accurate, (8) they are more scientific, (9) they are the legal units, (10) they are international.

*39. Scientific errors are usually reported as: (1) fractions of an inch, (2) decimals, (3) per cent error, (4) plus or minus, (5) absolute error.

40. When we report experimental errors, we do so: (6) to enable others to repeat the experiment and check our results, (7) to show how carefully we measured, (8) as busy work, (9) because it is traditional, (10) because to err is human.

*41. We report percentage errors because: (1) people think in percentages, (2) it is legal, (3) it is easier to compare errors, (4) it is easier than absolute error, (5) decimals are easier than fractions.

*42. Which of these is the best example of kinetic energy: (6) a gallon of fuel oil, (7) a box of Wheaties, (8) a student sitting in class, (9) a paratrooper jumping, (10) a ton of coal.

*43. One of the following has both potential and kinetic energy: (1) a gallon of fuel oil, (2) a ton of coal, (3) a burning building, (4) a box of Wheaties, (5) a parked car.

*44. A weight is supported by a string; the weight falls and breaks the string. This is an example of: (6) inertia, (7) potential energy, (8) kinetic energy, (9) mass, (10) a push or a pull.

45. If a weight tied to a string is travelling at the same speed along a circular path, then: (1) it has both kinetic and potential energy, (2) it has kinetic energy, (3) it has potential energy, (4) it has uniform velocity, (5) it has uniform acceleration.

46. Dynes or Newtons are defined in terms of: (6) inertia, (7) energy, (8) Newton's 1st law, (9) Newton's 2nd law, (10) Newton's 3rd law.

47. A swinging pendulum best illustrates: (1) force, (2) work, (3) speed, (4) velocity, (5) acceleration.

*48. If a 50 dyne force is operating toward the east, and a 100 dyne force is operating toward the west, we can show what happens with: (6) a 50 dyne vector, (7) a 50 dyne vector pointing east, (8) a 50 dyne vector pointing west, (9) a component of 50 dynes, (10) a resultant of 50 dynes.

49. In a vector diagram the scale is 1 cm. = 5 gr. We have a parallelogram with a diagonal 7 cm. long. This represents: (1) a component, (2) a resultant, (3) a component 7 cm. long, (4) a resultant of 35 gr., (5) a component of 35 gr.

50. The force needed to balance the force represented in question no. 49 is: (6) an equilabrant of 35 gr., (7) a equilibrant of 7 cm., (8) a resultant of 35 gr., (9) a resultant of 7 cm., (10) none of these.

*51. When we pay the power company for kilowatt-hours, we are paying for: (1) power, (2) force, (3) work, (4) 1000 watts of electricity, (5) none of these.

*52. In order to balance a 100 lb. boy at a distance of 12 ft. from the balancing point of a see-saw, a 75 lb. boy must be at a distance of: (6) 9 ft., (7) 6 ft., (8) 13.5 ft., (9) 16 ft., (10) 10 ft.

*53. If a machine has a distance ratio of 5/3, then: (1) the theoretical mech. advantage will be greater than 5/3, (2) the theoretical mech. advantage will be 5/3, (3) the theoretical M.A. will be less than 5/3, (4) the ratio of resistance to effort is 5/3, (5) the actual mechanical advantage is 5/3.

*54. When there is a difference between actual and theoreticl mechanical advantage, it is due to: (6) errors of measurement, (7) friction, (8) errors in arithmetic, (9) gravity, (10) there isn't any difference.

55. When a lever has its fulcrum at the center of gravity, we neglect the weight of the lever because: (1) it is insignificant, (2) it is a first class lever, (3) its moment is zero, (4) of friction, (5) of gravity.

*56. The theoretical mechanical advantage of an inclined plane is: (6) the angle of elevation, (7) the ratio of resistance to effort, (8) the height of the plane, (9) mechanical advantage plus friction, (10) the ratio of length to height.

*57. Assuming no friction in a set of pulleys, an effort of 24 pounds lifts a resistance of 120 pounds through a distance of 3 ft. This means that the effort must have travelled: (1) 3 ft., (2) 15 ft., (3) 5 ft., (4) 8 ft., (5) 40 ft.

58. One of the following <u>is not</u> a simple machine: (6) egg beater, (7) pliers, (8) fishing pole, (9) gangplank, (10) wheel.

*59. If a machine has a M.A. of less than 1: (1) it is very inefficient, (2) it may give advantage of position, (3) there is a lot of friction, (4) it is impossible to have such an M.A., (5) resistance is greater than effort.

60. The principle of moments is concerned with: (6) distances, (7) forces, (8) sum of forces and distances, (9) products of forces and distances, (10) mechanical advantage.

61. The principle of moments applied to the inclined plane is expressed as: (1) ExL = RxH, (2) ExR = LxH, (3) ExH = RxL, (4) L/H = E/R, (5) E/H = L/R.

62. The formula M/V is used to calculate: (6) density, (7) M.A., (8) efficiency, (9) buoyancy, (10) weight.

63. An automobile jack is a device used to multiply: (1) power, (2) velocity, (3) gravity, (4) force, (5) friction.

64. Which of the following is the best example of potential energy: (6) escaping air from a tire, (7) a beam of light, (8) an electric current, (9) a wound up watch spring, (10) a galloping horse.

*65. Neglecting air resistance, a falling body will move with: (1) uniform speed, (2) uniform acceleration, (3) uniform velocity, (4) curvilinear motion, (5) uniform power.

66. The results of an experiment are expressed in Kilogram-meters per second. We have measured: (6) work, (7) power, (8) force, (9) velocity, (10) momentum.

*67. The work output can never equal the work imput of a machine because: (1) the M.A. would be less than one, (2) as imput increases, efficiency decreases, (3) at least half the work put into the machine is used to overcome friction, (4) the ratio of effort distance to resistance distance is always greater than the ratio of resistance to effort, (5) as imput increases, output decreases.

*68. We can put more and more weight into a floating boat and it won't sink until: (6) the force of gravity increases, (7) the volume of the boat becomes greater than its weight, (8) the total weight of the boat becomes less than the weight of the displaced water, (9) the total weight of the boat becomes equal to the weight of the displaced water, (10) the total weight of the boat becomes more than the weight of the displaced water.

69. A sealed metal cylinder with a volume of 500 c.c. and a mass of 400 gr. is placed in a tank of fresh water. It will: (1) float half submerged, (2) sink to the bottom, (3) sink just below the surface, (4) sink just level with the surface, (5) have 4/5 of its height submerged.

70. A system of pulleys has five ropes supporting the load. Its M.A. is 4/1. Its efficiency is: (6) 25%, (7) 80%, (8) 90%. (9) 125%, (10) 20%.

*71. The period of a simple pendulum depends upon: (1) its length alone, (2) its mass alone, (3) the length of its arc, (4) the mass and the length, (5) mass and length of arc.

*72. A 500 gram frictionless car is at rest on a horizontal surface. A horizontal accelerating force of 1000 dynes acts upon it. The acceleration produced is: (6) 1/2 cm./sec./sec., (7) 1/4 cm./sec./sec., (8) 1 cm./sec./sec., (9) 2 cm./sec./sec., (10) 4 cm./sec./sec.

*73. The rotational equivalent of mass in Newton's second law is: (1) force, (2) angular acceleration, (3) rotational inertia, (4) rotational velocity, (5) centripetal force.

74. An aluminum block weighs 24 gr. and has a volume of 8 c.c. Its density is: (6) 1/3 gr., (7) 3 gr., (8) 16 gr./c.c., (9) 3 gr./c.c., (10) 1/3 gr./c.c.

75. Which term <u>does not</u> belong in the following list: (1) inclined plane, (2) ideal mechanical advantage, (3) pulley, (4) velocity, (5) efficiency.

76. Which term <u>does not</u> belong in the following list: (6) cm./sec., (7) radians, (8) r.p.s., (9) radians/sec., (10) moment of force.

77. A pulley system consists of one fixed double pulley and one movable double pulley, and the effort pulls down. The ideal mechanical advantage of this system is: (1) 1/4, (2) 1/3, (3) 4/1, (4) 3/1, (5) 5/1.

*78. A body starting at rest accelerates at 10 cm./sec./sec. for 5 seconds. During this time, its average speed is: (6) 10 cm./sec., (7) 25 cm./sec., (8) 50 cm./sec., (9) 100 cm./sec., (10) 250 cm./sec.

79. The body described in question 78 will have traveled: (1) 25 cm., (2) 50 cm., (3) 100 cm., (4) 125cm., (5) 250 cm.

80. The final speed attained by the body in question 78 will be: (6) 10cm./sec., (7) 25 cm./sec., (8) 50 cm./sec., (9) 125 cm./sec., (10) 250 cm./sec.

81. A pendulum's period may be made shorter by: (1) shortening it, (2) lengthening it, (3) making it heavier, (4) making it lighter, (5) changing the length of its arc.

82. Water will fly off of a rotating wheel and travel in a straight line. This is accounted for by: (6) inertia, (7) momentum, (8) velocity, (9) acceleration, (10) potential energy.

*83. A single fixed frictionless pulley can produce a change in: (1) force, (2) friction, (3) work, (4) direction, (5) power.

84. If a rock and a lump of coal both lose 2 kilograms of their weight when they are submerged in water, then they are alike in: (6) volume, (7) mass, (8) weight, (9) density, (10) specific gravity.

85. Rate of change of velocity is: (1) speed, (2) acceleration, (3) inertia, (4) force, (5) moment.

*86. If three non-parallel forces are in equilibrium and one of the forces is considered as an equilibrant, the other two are: (6) resultants, (7) scalers, (8) tensions, (9) components, (10) absolutes.

*87. In the law of gravitation, the force of gravity is: (1) constant, (2) proportional to distance alone, (3) proportional to the products of masses and distances, (4) proportional to the products of the mass and inversely proportional to the square of distance, (5) proportional to the product of masses and square of distances.

*88. Storm jackets are lined with fluffy material because this material is: (6) a poor radiator of heat, (7) a good radiator of heat, (8) of low specific heat, (9) a good conductor of heat, (10) a poor conductor of heat.

89. An aluminum roof keeps a building cooler in the heat of the sun because the aluminum: (1) is a good conductor, (2) is a poor conductor, (3) is a good radiator, (4) is a poor radiator, (5) has a high thermal capacity.

90. A liquid boils at 110°C. On the Fahrenheit scale this is about: (6) 60°, (7) 92°, (8) 180°, (9) 223°, (10) 230°.

*91. Which of the following expands at the same rate when heated: (1) gasses, (2) liquids, (3) solids, (4) liquids and gasses, (5) liquids and solids.

92. If 0.2 calories will raise the temperature of 1 gr. of a solid 5°C, the specific heat of the solid is: (6) 0.004, (7) 0.04, (8) 0.4, (9) 4, (10) 1.0.

*93. Assuming no outside source of heat, as a liquid evaporates it will: (1) solidify, (2) raise the temperature, (3) lower the temperature, (4) boil, (5) remain the same.

94. If the temperature of the air is at the dew point, the relative humidity is: (6) zero, (7) between 1% and 99%, (8) 100%, (9) over 100%, (10) can't tell with the information given.

*95. If the difference between the wet and dry bulb thermometer readings is small, the relative humidity is: (1) high, (2) low, (3) close to zero, (4) close to 100, (5) can't tell with this information.

*96. Which of the following instruments is used to measure relative humidity: (6) thermostat, (7) mercury barometer, (8) aneroid barometer, (9) hydrometer, (10) hygrometer.

*97. Which of the following instruments operates because of the unequal expansion of metals: (1) thermostat, (2) mercury barometer, (3) aneroid barometer, (4) Hydrometer, (5) hygrometer.

98. If the temperature out of doors is 20°F. and you pick up each of the following, which will <u>feel</u> coldest to your hand: (6) an empty milk bottle, (7) an iron wrench, (8) a newspaper, (9) a piece of wood, (10) they would all feel equally cold.

*99. If the temperature out of doors is 20°F. and you pick up each of the following, which will actually be the coldest: (1) an empty milk bottle, (2) an iron wrench, (3) a newspaper, (4) a piece of wood, (5) they would all be equally cold.

*100. A change from 20° to 30° on the centigrade scale is equivalent to a Fahrenheit change of: (6) 10°, (7) 12°, (8) 15.5°, (9) 18°, (10) 22.5°.

101. The principle way in which the sun's heat reaches the earth is by: (1) radiation, (2) convection, (3) conduction, (4) conduction and radiation, (5) convection and conduction.

*102. If the temperature of an enclosed gas remains constant and its volume is doubled, its pressure will be: (6) 4 times as much, (7) 2 times as much, (8) the same, (9) 1/2 as much, (10) 1/4 as much.

*103. If a gas is cooled to absolute zero: (1) its volume will be zero, (2) its pressure will be high, (3) its molecules will have no elasticity, (4) its molecules will have no kinetic energy, (5) its specific heat will be zero.

104. Heating a liquid to a vapor and then condensing it describes the process of: (6) vaporization, (7) condensation, (8) distillation, (9) melting, (10) boiling.

*105. The desert nomad wears loose woolen clothing because: (1) it absorbs perspiration, (2) it doesn't absorb perspiration, (3) it is a good conductor of heat, (4) it is a poor conductor of heat, (5) it is a good radiator of heat.

106. The amount of heat necessary to change one gram of a solid to liquid at its melting point is known as: (6) heat of fusion, (7) heat of vaporization, (8) specific heat, (9) thermal capacity, (10) temperature gradient.

*107. Boyle's law deals with changes in: (1) absolute temperature, (2) volume only, (3) pressure and volume, (4) pressure and temperature, (5) temperature and volume.

*108. Charles' law deals with changes in: (6) absolute temperature, (7) absolute temperature and volume, (8) pressure and volume, (9) pressure and temperature, (10) volume only.

*109. Wet clothing will dry most slowly in a room at 68°F that has: (1) a low relative humidity, (2) a low dew point, (3) a high relative humidity, (4) the heat on, (5) the heat off.

110. Mechanical energy is most frequently changed to heat energy by a process of: (6) evaporation, (7) friction, (8) condensation, (9) expansion, (10) compression.

111. Heat energy is most frequently changed to mechanical energy by a process of: (1) evaporation, (2) friction, (3) condensation, (4) expansion, (5) compression.

112. One of the following is not an example of an external combustion engine: (6) Newcommen's engine, (7) Watt's engine, Diesel engine, (9) turbine, (10) multiple expansion engine.

113. In a gasoline engine the fuel mixture is prepared in the: (1) cylinder, (2) fuel pump, (3) gas tank, (4) carburetor, (5) distributor.

114. The Diesel engine does not have: (6) fuel pump, (7) fuel tank, (8) spark plugs, (9) cylinders, (10) an exhaust.

*115. The first law of thermodynamics states that: (1) heat cannot of itself pass from a hot body to a cold body, (2) heat cannot of itself pass from a cold body to a hot body, (3) heat engines are not very efficient, (4) energy cannot be changed without some loss, (5) the energy of heat processes is always conserved.

116. Which of the following carries within itself everything necessary for combustion: (6) rocket, (7) turbo-jet, (8) turbo-prop, (9) Diesel, (10) Otto engine.

117. You are standing on a station platform as a train one mile away approaches the station. The engineer blows the whistle. The tone you hear: (1) is the same as that heard by the engineer, (2) has a lower pitch than the whistle, (3) has the same pitch as the whistle, (4) has a higher pitch than the whistle, (5) is one-half the pitch of the whistle.

118. Only one of the following can occur when two waves of different frequencies come together: (6) resonance, (7) reflection, (8) beats, (9) Doppler effect, (10) refraction.

119. The quality of a tone from a musical instrument depends upon: (1) its overtones alone, (2) the type of instrument and its overtones, (3) its loudness, (4) its pitch, (5) the speed of sound.

120. If a vibrating string has its tension increased and its length decreased: (6) it will have better quality, (7) the amplitude increases, (8) the amplitude decreases, (9) the pitch increases, (10) the pitch decreases.

121. The reciprocal of pitch is: (1) frequency, (2) velocity, (3) amplitude, (4) period, (5) quality.

122. When a second body is caused to vibrate at the same frequency as a first, the phenomenon is called: (6) interference, (7) beats, (8) refraction, (9) Doppler effect, (10) resonance.

*123. Waves bend when they are: (1) diffracted, (2) refracted, (3) reinforced, (4) interfering, (5) causing beats.

124. One of the following <u>is not</u> characteristic of sound waves: (6) pitch, (7) intensity, (8) transverse, (9) beats, (10) speed.

125. The illumination in foot-candles received from a 100 candle power source at a distance of 10 ft. is: (1) 1, (2) 10, (3) 100, (4) 1000, (5) 10,000.

126. A clear pane of glass will not cast much shadow because: (6) it reflects light, (7) it diffracts light, (8) it refracts light, (9) it transmits light, (10) the speed of light increases in glass.

*127. Materials such as frosted glass which allow the passage of some light, but through which we cannot see, are said to be: (1) opaque, (2) electro-luminescent, (3) fluorescent, (4) transparent, (5) translucent.

*128. When a pure blue light is passed through a pure red filter: (6) no light is transmitted, (7) red light is transmitted, (8) blue light is transmitted, (9) red and blue light is transmitted, (10) purple light is transmitted.

*129. When a pure blue light is flashed on a pure red wall, the wall will show: (1) white, (2) black, (3) red and blue, (4) blue, (5) red.

130. A black and white photographic film contains compounds of: (6) copper, (7) aluminum, (8) lead, (9) silver, (10) mercury.

131. The primary source of practically all the energy that we use comes from: (1) water power, (2) atomic energy, (3) oil, (4) coal, (5) the sun.

*132. Planets are not considered as parts of constellations because they are: (6) too bright, (7) too dim, (8) giving off reflected light, (9) too close to the earth, (10) not fixed in their positions.

133. Who among the following did not recognize a heliocentric theory: (1) Newton, (2) Kepler, (3) Copernicus, (4) Ptolemy. (5) Galileo.

*134. The "days" are about 24 hours long at the south pole during the month of: (6) September, (7) December, (8) March, (9) June, (10) January.

135. The apparent daily motion of the sun around the earth is caused by the: (1) earth's being tipped 23°, (2) earth travelling around the sun, (3) passage of the sun around the earth, (4) rotation of earth on its axis, (5) drift of sun and planets among the stars.

136. On a clear night we can accurately tell time by: (6) number of meteors, (7) movement of constellations, (8) phase of the moon, (9) number of stars in sky, (10) revolution of earth.

137. Asteroids are: (1) nebulae, (2) novae, (3) fragments of a planet, (4) comets, (5) meteors.

*138. Kepler's contribution to astronomy was his: (6) discovery of Neptune, (7) observation of the moons of Jupiter, (8) advancing a geocentric theory, (9) discovery of the telescope, (10) calculation of elliptical orbits.

139. One of the following <u>can not</u> be used in support of a geocentric theory: (1) eccentrics and epicycles, (2) seasons, (3) rising and setting of the sun, (4) movement of the moons of Jupiter, (5) the retrograde motion of the planets.

140. Which of the following <u>is not</u> visible to the naked eye at any time: (6) Uranus, (7) Mercury, (8) Neptune, (9) comets, (10) meteors.

141. The light emitting portion of the sun is the: (1) photosphere, (2) reversing layer, (3) chromosphere, (4) corona, (5) sun-spots.

*142. The most accurate method for determining the age of the earth is by measuring: (6) tidal effects, (7) rate of erosion of continents, (8) amount of salt in the oceans, (9) rate of radio-active decay of certain rocks, (10) the rate of deposit of sedimentary rock.

*143. The astronomical unit is: (1) a light year, (2) a million miles, (3) a parsec, (4) mean distance of earth from sun, (5) 186,000 miles.

*144. The time at which the sun's rays reach the Tropic of Cancer and start moving south is called: (6) Spring, (7) Vernal equinox, (8) Autumnal equinox, (9) Winter solstice, (10) Summer solstice.

*145. A monistic theory of cosmogony which claims a continuous creation of hydrogen as the building blocks of matter was advocated by: (1) Whipple, (2) Hoyle, (3) Chamberlain, (4) Kant-Laplace, (5) Einstein.

146. The appearance of the moon at either 3/8 or 5/8 of its cycle is called: (6) perigee, (7) apogee, (8) gibbous, (9) full, (10) crescent.

147. The light producing surface of the sun is the: (1) corona, (2) photosphere, (3) nucleus, (4) reversing layer, (5) ionosphere,

148. The apparent easterly drift of the planets is known as: (6) revolution, (7) rotation, (8) perturbation, (9) retrograde motion, (10) occulation.

149. "Shooting stars" are really: (1) planets, (2) planetoids, (3) asteroids, (4) comets, (5) meteors.

*150. The path of the sun, the moon, and planets among the stars is known as the: (6) epicycle, (7) eccentric, (8) zenith, (9) ecliptic, (10) perturbation .

151. The longest unit of length used in astronomy is the: (1) thousand miles, (2) million miles, (3) light year, (4) parsec, (5) astronomical unit.

*152. An eclipse of a star by the moon is called: (6) lunar eclipse, (7) occulation, (8) perigee, (9) apogee, (10) gibbous.

153. The planet with the most moons is: (1) Saturn, (2) Jupiter, (3) Uranus, (4) Mars, (5) Neptune.

154. The planet which was discovered mathematically is: (6) Mars, (7) Jupiter, (8) Uranus, (9) Saturn, (10) Neptune.

*155. The approximate length of an astronomical unit is: (1) 1 thousand miles, (2) 186,000 miles, (3) a million miles, (4) 93 million miles, (5) over a billion miles.

*156. Two pith balls, 2 cm. apart, are both charged by a glass rod that has been rubbed with silk. The distance between them is increased to 4cm. As a result they will: (6) attract with twice the force, (7) attract with four times the force, (8) attract with 1/4 the force, (9) repel with 1/4 as much force, (10) repel with four times the force.

157. If the inside and outside of a glass jar are coated with a good conductor, the inside connected to one side of an electric source and the outside connected to the other side of the source, the device will act as: (1) a reactance, (2) resistance, (3) choke, (4) conductance, (5) capacitance.

*158. An iron bar is suspended by a string. The south pole of the magnet attracts one end of the bar. That end was: (6) the south pole of a magnet, (7) the north pole of a magnet, (8) either unmagnetized or a north pole, (9) either unmagnetized or a south pole, (10) unmagnetized.

*159. Which of the following is not true of the electron: (1) it is a negative charge of electricity, (2) it moves freely along a dialectric, (3) it is smaller in size than the hydrogen atom, (4) it is part of all matter, (5) it is present in small quantities in positively charged bodies.

160. If a knife blade is stroked from the handle to the tip with the north pole of a magnet: (6) the end near the handle will be a north pole, (7) the end near the handle will not be magnetized, (8) the tip will be a north pole, (9) the entire knife will be a south pole, (10) the blade will not be magnetized.

*161. If a glass rod is rubbed with silk, the rod: (1) loses electrons, (2) gains electrons, (3) acquires a negative charge, (4) loses protons, (5) gains protons.

*162. When a magnetic compass is shielded from nearby magnetic substances and from iron and steel, it will always point: (6) to the true north, (7) to the northwest, (8) to the magnetic north pole, (9) to the northeast, (10) not necessarily to any of these.

*163. When all molecules of a magnetizable substance are oriented, we say that the resulting magnet has: (1) high permeability, (2) saturation, (3) high retentivity, (4) low permeability, (5) low retentivity.

164. If a charged glass rod is brought near to, but not touching, the metal knob of an electroscope: (6) the leaves diverge and are positively charged, (7) the leaves come together and are positively charged, (8) the leaves diverge and are negatively charged, (9) the leaves come together and are negatively charged, (10) none of these things will necessarily happen.

*165. Which of the following is not true of lines of forces: (1) they show the direction of the magnetic field, (2) they never cross one another, (3) they repel each other, (4) they start at the south pole and end at the north pole, not going through the magnet, (5) their number determines the strength of the field.

*166. A Leyden jar is a kind of: (6) static machine, (7) electroscope, (8) condenser, (9) electrophorous, (10) conductor.

*167. Two pith balls initially 2 cm. apart are charged with a rubber rod that has been rubbed with fur. They are then moved until they are 6 cm. apart. As a result, they will: (1) attract with three times as much force, (2) repel with three times as much force, (3) attract with nine times as much force, (4) repel with 1/9 as much force, (5) attract with 1/9 as much force.

168. An electroscope is charged by bringing a chared rubber rod near to, but not touching, its knob. The finger is momentarily touched to the knob and then the rod is removed. The electroscope: (6) is charged positively by conduction, (7) was charged negatively by conduction, (8) was positively charged by induction, (9) was negatively charged by induction, (10) remains uncharged.

*169. One of the following <u>does not</u> produce any permanent magnetism in a steel bar: (1) heating it and allowing it to cool near a strong magnet, (2) stroking it in one direction with a strong magnet, (3) placing it in a strong magnetic field, (4) placing it in a coil through which an alternating current is flowing, (5) placing it in a coil through which a direct current is flowing.

170. An iron bar is hung so that it swings freely on a string. The south pole of a magnet will <u>only</u> attract one end of the bar. That end is: (6) a south pole, (7) a north pole, (8) unmagnetized, (9) either unmagnetized or a south pole, (10) either unmagnetized or a north pole.

171. The perfect conductor is: (1) silver, (2) copper, (3) steel, (4) aluminum, (5) unknown.

*172. Two magnetic poles which are attracting each other at a distance one centimeter apart are moved until they are ten centimeters apart, the attraction between the poles will be: (6) increased by 100, (7) increased by 10, (8) reduced by 1/10th, (9) reduced by 1/100 th, (10) the same.

173. Alnico is an alloy from which strong permanent magnets can be made. This means that alnico has: (1) low permeability, (2) high permeability and low retentivity, (3) high permeability and high retentivity, (4) is saturated, (5) low permeability.

174. The amount of work done when a condenser is discharged is: (6) dependent on the size of the condenser, (7) dependent on the kind of charge present, (8) is measured in amperes, (9) is measured in kilowatts, (10) is measured in volts.

175. If we wish to increase the strength of an electro-magnet without using more current, we can: (1) use more insulation on the wires, (2) increase the number of turns on the coil, (3) decrease the number of turns on the coil, (4) use copper in place of iron in the core, (5) decrease the size of the core.

176. When a current of 200 milliamperes flows through a resistance of 500 ohms for 4 minutes, the e.m.f. across the resistor must be: (6) 40,000 volts, (7) 400 watts, (8) 100 volts, (9) 40 watts, (10) 10 volts.

177. Which of the following will not operate on a.c.: (1) electrolysis, (2) washing machine, (3) resistors, (4) capacitors, (5) transformers.

178. If an electric iron draws 1000 watts and the a.c. voltage is 100 the amperage drawn is about: (6) 120,000, (7) 100,000, (8) 120, (9) 12, (10) 7.

179. The rate of flow of an electric current is measured in: (1) coulombs, (2) electrons, (3) ohms, (4) amperes, (5) volts.

180. In electroplating, the amount of metal deposited is directly proportional to: (6) the electrolyte, (7) the size of the cathode, (8) the size of the object being plated, (9) coulombs used, (10) resistance of the circuit.

181. The field around a current-carrying wire can be represented by: (1) lines parallel to the wire pointing in the direction opposite to current flow, (2) lines parallel to the wire pointing in the same direction as the current flow, (3) an ellipse in the same place as the wire, (4) concentric circles in the same plane as the wire, (5) concentric circles in a plane at right angles to the wire.

182. If a copper wire and an iron wire, both of the same length and cross section, are connected in series with a circuit: (6) the greater voltage drop is across the copper wire, (7) the greater voltage drop is across the iron wire, (8) more current flows through the copper wire, (9) more current flows through the iron wire, (10) none of the above is true.

*183. Which of the following is essential to all of these: telephones, loudspeakers, television receivers, generators, motors, doorbells: (1) potentiometers, (2) reactance, (3) condensers, (4) fields, (5) electron tubes.

184. When we turn out an electric light, all of the lights in the house do not go out because: (6) light bulbs have low resistance, (7) the current is fused, (8) light bulbs have high resistance, (9) houses are wired in parallel, (10) houses are wired in series.

*185. Three resistances of 2, 4, and 6 respectively are connected in a parallel circuit. The total e.m.f. of the circuit is 24 volts. The current registering in an ammeter at the terminals of the circuit will be: (1) 12 amperes, (2) 6 amperes, (3) 22 amperes, (4) 2 amperes, (5) 11 amperes.

186. A transformer <u>can not</u> change: (6) amperes, (7) volts, (8) coulombs, (9) D.C. to A.C., (10) resistance.

187. The flow of current in an a.c. circuit can be reduced without any large power change by means of: (1) step-up transformer, (2) step-down transformer, (3) resistors in series, (4) condensers in parallel, (5) a choke coil.

*188. The fact that a hot filament in a partial vacuum emitted electrons was first observed by : (6) Faraday, (7) Oersted, (8) Einstein, (9) Edison, (10) DeForrest.

*189. The magnetic field around a current-carrying wire was first observed by: (1) Faraday, (2) Oersted, (3) Einstein, (4) Edison, (5) DeForrest.

190. A device which converts electrical to mechanical energy is: (6) motor, (7) generator, (8) converter, (9) inverter, (10) transformer.

191. The rate of flow of an electric current is measured in: (1) amperes, (2) volts, (3) coulombs, (4) watts, (5) ohms.

*192. One of the following <u>does not</u> effect the resistance of a wire: (6) length, (7) temperature, (8) voltage, (9) type of metal used, (10) cross-section.

*193. If a voltmeter is connected in series with a circuit being tested, it will: (1) give a false reading, (2) read amperes, (3) burn out, (4) read ohms, (5) read volts.

194. If a hard rubber rod is rubbed with fur, the fur will: (6) gain electrons, (7) lose conductivity, (8) acquire a negative charge, (9) lose electrons, (10) gain conductivity.

195. The secondary ommission at the plate of an electron tube: (1) consists of positive charges, (2) disappears when the plate warms up, (3) is minimized by the suppressor, (4) is controlled by the screen grid, (5) is eliminated if we use a coated cathode.

*196. If electrons flow through a triode, one of the following is not true: (6) the plate is at a relatively high positive voltage, (7) the cathode must be heated, (8) the grid must be positive with respect to the plate, (9) the grid must be positive with respect to the cathode, (10) the cathode must be negative with respect to the plate.

197. If triode A is used to amplify a signal from triode B; (1) the cathodes of A and B must be in series, (2) the plate of B should be connected to the grid of A, (3) the plate of A should be connected to the grid of B, (4) the grid of A should be connected to the grid of B, (5) the plate of A should be connected to the plate of B.

*198. An electronic circuit differs from a purely electrical circuit in that: (6) it has a backward flow of electrons, (7) it has no resistance, (8) electrons flow through wires, (9) electrons flow through gasses, (10) there is no difference.

*199. The resistance to the flow of current in a coil due to the frequency of an alternating current is known as: (1) cycles per second, (2) impedence, (3) reactance, (4) inductance, (5) reluctance.

*200. In an a.c. circuit, the combined effects of resistance and reactance are called: (6) inductance, (7) reluctance, (8) transconductance, (9) impedence, (10) frequency.

*201. The decomposition of a compound by means of electricity is called: (1) ionization, (2) decomposition, (3) displacement, (4) electrolysis, (5) none of these.

*202. Which of the following will produce a useful electric current: (6) rubber rubbed with fur, (7) glass rubbed with silk, (8) two strips of the same metal in salt solution, (9) a wire cutting an electric or magnetic field, (10) a coil of wire wound around a magnet.

203. If we wish to transmit electric power over long distances, we shoul use: (1) High voltage direct current, (2) high voltage, low amperage direct current, (3) low voltage, (4)low voltage, high amperage alternating current, (5) high voltage, low amperage alternating current.

204. The power of an alternating current is determined by: (6) dividing current by reactance, (7) multiplying amperes by volts, (8) multiplying amperes by volts times a number more than one, (9) multiplying amperes by volts times a number less than one, (10) reading a watt-hour meter.

*205. If a transformer has 10 turns in the primary and 100 turns in the secondary: (1) secondary current is 100 times the primary, (2) secondary volts are ten times the primary, (3) secondary volts are 1/10 the primary, (4) amperes increase, (5) volts decrease.

*206. In a simple cell with copper and zinc electrodes and dilute hydrochloric acid, the electricity is produced by: (6) the copper, (7) the zinc, (8) the hydrochloric acid, (9) the copper and the zinc, (10) none of these.

207. Oxidation occurs in nature when: (1) water boils, (2) ice melts, (3) it rains, (4) it snows, (5) cloth rots.

208. If potassium reacts with water to produce potassium hydroxide and hydrogen, the reaction is an example of: (6) the oxidation of hydrogen, (7) the reduction of potassium, (8) decomposition, (9) displacement, (10) combination.

209. In which of the following are there no electrons: (1) lightning, (2) alternating current, (3) ions, (4) nucleus of an atom, (5) direct current.

*210. If a concentrated solution has more solute added to it, it will be: (6) saturated, (7) supersaturated, (8) dilute, (9) precipitated, (10) not necessarily any of these.

211. If a bottle is labelled "Shake Well Before Using" it contains: (1) a concentrated solution, (2) an emulsion, (3) a tincture, (4) a dilute solution, (5) a saturated solution.

212. Alpha particles are: (6) helium nuclei, (7) electrons, (8) protons, (9) neutrons, (10) energy waves.

213. If a concentrated solution has more solute added to it,: (1) a precipitate will form, (2) it will be saturated, (3) it will be more concentrated, (4) it will be supersaturated, (5) crystals will be formed.

*214. If an atom of an element has a neutron added to its nucleus,: (6) it will become a different element, (7) its atomic number will change, (8) its atomic weight will change, (9) it will give off alpha particles, (10) it will give off gamma radiation.

215. Isotopes are: (1) atoms of the same element with a different number of protons, (2) atoms of different elements with the same number of neutrons, (3) atoms of the same element with a different number of electrons, (4) atoms of the same element with a different number of neutrons, (5) none of these.

216. The heating of iron ore with coke to produce iron is an example of: (6) simple conbination, (7) simple decomposition, (8) oxidation, (9) reduction, (10) oxidation and reduction.

*217. If an isotope is made in a uranium pile: (1) it is unstable, (2) it is always a beta emitter, (3) it always gains electrons, (4) it always gains protons, (5) it will never be found in nature.

218. If an electron tube is to be used as an amplifier, it must have: (6) at least two elements, (7) at least three elements, (8) at least four elements, (9) at least five elements, (10) direct current on the grid.

219. A small a.c. voltage can control the flow of a large d.c. voltage by means of a : (1) heater, (2) filament, (3) grid, (4) screen, (5) plate.

220. A tube that can be used for both the detection and amplification of radio signals is: (6) a diode, (7) a multi-unit tube, (8) a multi-purpose tube, (9) a power tube, (10) a rectifier.

221. The pentode differs from the tetrode in that it has a: (1) plate, (2) cathode, (3) screen, (4) suppressor, (5) grid.

222. The tetrode differs from the triode in that it has a:(6) plate, (7) cathode, (8) screen, (9) suppressor, (10) grid.

223. The triode differs from the diode in that it has a: (1) plate, (2) cathode, (3) screen, (4) suppressor, (5) grid.

*224. The secondary emission at the plate of an electron tube: (6) consists of positive charges, (7) is caused by the temperature of the screen grid, (8) disappears as the plate warms up, (9) is minimized by the suppressor, (10) is eliminated if we use a coated cathode.

*225. If we wish to rectify a current, we must use a: (1) diode to change a.c. to d.c., (2) diode to change d.c. to a.c., (3) pentode to give a non-pulsating d.c. (4) tetrode to give 60 cycles, (5) suppressor to smooth out the a.c.

226. The modern radio has fewer tubes than comparable earlier sets because: (6) it uses printed circuits, (7) broadcasting stations are more numerous, (8) of the development of multi-purpose tubes, (9) of the development of multi-unit tubes, (10) of the development of unit tubes.

227. Ordinary air is a true solution of: (1) gasses, (2) of gasses with some suspended solids, (3) gasses and liquids, (4) gasses with liquids and solids suspended in it, (5) solids, liquids, and gasses.

*228. Water can be made chemically pure by: (6) boiling, (7) filtering, (8) sedimentation, (9) chlorination, (10) distillation.

229. One of the following is a chemical change: (1) boiling of water, (2) filtering, (3) distillation, (4) freezing of water, (5) electrolysis of water.

230. One of the following <u>is not</u> a solution: (6) brass, (7) sea water. (8) orange-ade, (9) copper, (10) bronze.

APPENDIX B

JURY

Jury from Massachusetts State Teachers Colleges at:

1. Bridgewater,	Otis Alley, Ph. D.
2. Boston,	Francis McCarthy, Ed. D.
3. Framingham,	Alice M. Glover, Ed. D.
4. Lowell,	Patricia Gerht, M. A.
5. North Adams,	John J. Seman, Ph. D.
6. Salem,	Earle Collins, M. A.
7. Westfield,	Albert Genua, Ph. D.
8. Worcester,	Edmund Osborn, M. A.

A TEST OF GENERAL PHYSICAL SCIENCE

An instrument for measuring some of the outcomes of Physical Science as it is offered in the General Education Program of the State Teachers Colleges of Massachusetts.

Prepared by:

William H. Malone
State Teachers College
Lowell, Massachusetts

FORM E

Directions

Do not open the test booklet until you are told to do so. This examination is made of a selection of items designed to test your knowledge of certain fundamental concepts of the physical sciences.

It will be to your advantage to answer all questions. You may answer questions even when you are not sure your answers are correct. Your score will be the number of correct answers. There is no penalty for incorrect answers.

You are to mark the answers to all questions on the separate answer sheet that accompanies this booklet. When you have decided which answer you wish to choose for a question, blacken the space between the dotted lines under the matching number on your answer sheet. Use a soft pencil and make a heavy black line which fills the space between these dotted lines. Do not make any stray markings on the answer sheet. If you wish to change your answer, erase it completely and then mark the new space. If you answer in more than one space to a question, that question will not be counted in the scoring. Do not mark in your test booklet.

Each question is followed by five choices. Select the choice that best answers the question and blacken the space beneath its number on the answer sheet.

SELECT THE BEST ANSWER

Metric units are preferred to English units of measurement because
(1) they make computation easier
(2) they tend to be more accurate
(3) they are more scientific
(4) they are the legal units
(5) they are international

Neglecting air resistance, a falling body will move with
(1) uniform speed
(2) uniform acceleration
(3) uniform velocity
(4) uniform power
(5) curvilinear motion

If three non-parallel forces are in equilibrium and one of the forces is considered as the equilibrant, the other two are
(1) resultants
(2) scalers
(3) tensions
(4) components
(5) absolutes

To change meters to centimeters we
(1) divide by 10
(2) multiply by 100
(3) divide by 100
(4) multiply by 1000
(5) divide by 1000

The metric standard of weight is the
(1) gram
(2) kilogram
(3) erg
(4) meter
(5) liter

When there is a difference between actual and theoretical mechanical advantage it is usually due to
(1) errors of measurement
(2) friction
(3) errors in arithmetic
(4) gravity
(5) none of these

7. We can put more and more weight into a floating boat and it won't sink until
(1) the force of gravity increases
(2) the volume of the boat becomes greater than its weight
(3) the total weight of the boat becomes less than the weight of the displaced water
(4) the total weight of the boat becomes equal to the weight of the displaced water
(5) the total weight of the boat becomes greater than the weight of the displaced water

8. In a vector diagram the scale is one centimeter equals five grams. If we have a resultant represented by a line seven centimeters long, the force needed to balance it is
(1) an equilibrant of 35 grams
(2) an equilibrant of 7 centimeters
(3) a resultant of 35 grams
(4) a resultant of 7 centimeters
(5) none of these

9. If a 50 dyne force is operating toward the east and a 100 dyne force is operating toward the west, we can represent what is happening with
(1) a 50 dyne vector
(2) a 50 dyne vector pointing east
(3) a 50 dyne vector pointing west
(4) a component of 50 dynes
(5) a resultant of 50 dynes

10. On a metric vernier caliper the smallest marking on the vernier scale is equal to
(1) a centimeter
(2) a millimeter
(3) a micron
(4) a tenth of a centimeter
(5) a tenth of a millimeter

11. Scientific errors are usually reported as
(1) fractions of an inch
(2) decimals
(3) percentage errors
(4) plus or minus
(5) absolute errors

12. A single fixed frictionless pulley can produce a change in
(1) force
(2) friction
(3) work
(4) direction
(5) power

13. Machines are not used to
(1) convert one kind of energy to another
(2) multiply force
(3) increase speed
(4) decrease resistance
(5) change the direction of a force

14. If a machine has a mechanical advantage of less than one, it follows that
(1) it is very inefficient
(2) it may give advantage of position
(3) there is a lot of friction present
(4) it is impossible to have such a mechanical advantage
(5) resistance is greater than effort

15. A body at rest accelerates at ten centimeters per second per second for five seconds. During this time its average speed is
(1) 10 cm. per sec.
(2) 25 cm. per sec.
(3) 50 cm. per sec.
(4) 100 cm. per sec.
(5) 250 cm. per sec.

16. The rotational equivalent of the mass in Newton's second law is
(1) force
(2) angular acceleration
(3) rotational inertia
(4) rotational velocity
(5) centripetal force

17. According to Newton's law of unive gravitation, the force of gravity
(1) constant
(2) proportional to the distance
(3) proportional to the products o masses and distances
(4) proportional to the product of the masses and inversely proportional to the square of the distance
(5) proportional to the product of masses and the square of the distance

18. The apparent easterly drift of the planets is known as
(1) revolution
(2) rotation
(3) perturbation
(4) retrograde motion
(5) occulation

19. Planets are not considered as parts of constellations because they are
(1) too bright
(2) too dim
(3) shining with reflected light
(4) too close to the earth
(5) not fixed in their positions

20. The "days" are about 24 hours long the south pole during the month of
(1) September
(2) December
(3) March
(4) June
(5) January

21. Kepler's contribution to astronomy was his
(1) discovery of Neptune
(2) observation of the moons of Jupiter
(3) advancing of a geocentric theory
(4) discovery of the telescope
(5) calculation of elliptical orbits

22. The most accurate method for measuring the age of the earth is by measuring the
(1) tidal effects
(2) rates of erosion
(3) amount of salt in the oceans
(4) rate of radio-active decay of certain rocks
(5) rate of deposit of sediments

23. One of the following cannot be used in support of a geocentric theory
(1) eccentrics and epicycles
(2) seasons
(3) rising and setting of the sun
(4) movements of the moons of Jupiter
(5) retrograde motions of planets

24. A black and white photographic film contains compounds of
(1) copper
(2) aluminum
(3) lead
(4) silver
(5) mercury

25. When a pure blue light is flashed on a pure red wall, the wall will show
(1) white
(2) black
(3) red and blue
(4) blue
(5) red

26. Waves bend when they are
(1) diffracted
(2) refracted
(3) reinforced
(4) interfering
(5) causing beats

27. Most thermometers operate on the principle of
(1) radiation
(2) transmission
(3) conversion
(4) expansion
(5) conduction

28. A change from 20° to 30° on the Centigrade scale is equivalent to a Fahrenheit degree change of
(1) 10
(2) 12
(3) 15.5
(4) 18
(5) 22.5

29. Assuming no outside source of heat, as a liquid evaporates it will
(1) solidify
(2) raise the temperature
(3) lower the temperature
(4) boil
(5) stay at the same temperature

30. If the temperature out of doors is 20° F. and you pick up each of the following, which will actually be the coldest
(1) an empty milk bottle
(2) an iron wrench
(3) a piece of wood
(4) a newspaper
(5) they'll all be equally cold

31. Wet clothing will dry most slowly in a room at 68° F. that has
   (1) low relative humidity
   (2) a low dew point
   (3) high relative humidity
   (4) the heat on
   (5) the heat off

32. Boyle's law deals with changes in
   (1) absolute temperature
   (2) volume only
   (3) pressure and volume
   (4) pressure and temperature
   (5) temperature and volume

33. Water reaches its maximum density at
   (1) 0° Centigrade
   (2) 4° Centigrade
   (3) 100° Centigrade
   (4) as ice
   (5) as steam

34. The decomposition of a compound by means of electricity is called
   (1) ionization
   (2) decomposition
   (3) displacement
   (4) electrolysis
   (5) none of these

35. If an atom of an element has a neutron added to its nucleus
   (1) it will become a different element
   (2) its atomic number will change
   (3) its atomic weight will change
   (4) it will give off alpha particles
   (5) it will emit beta radiation

36. If an isotope is made in a uranium pile
   (1) it is unstable
   (2) it is always a beta emitter
   (3) it always gains electrons
   (4) it always gains protons
   (5) it will never be found in nature

37. When all the molecules of a magnetizable substance have been oriented, we say that the resulting magnet has
   (1) high permeability
   (2) saturation
   (3) high retentivity
   (4) low permeability
   (5) low retentivity

38. The magnetic field around a current carrying wire was first observed by
   (1) Faraday
   (2) Oersted
   (3) Einstein
   (4) Edison
   (5) DeForrest

39. Two magnetic poles which are attracting each other at a distance of one centimeter apart are moved until they are ten centimeters apart. The attraction between the poles will be
   (1) increased by 100
   (2) increased by 10
   (3) reduced by 1/10th
   (4) reduced by 1/100th
   (5) the same

40. One of the following does <u>not</u> produce any permanent magnetism in an iron bar
   (1) heating it and allowing it to cool near a strong magnet
   (2) stroking it in one direction with a strong magnet
   (3) placing it in a strong magnetic field
   (4) placing it in a coil through which an alternating current is flowing
   (5) placing it in a coil through which a direct current is flowing

A milli-ammeter would read
(1) thousandths of an ampere
(2) thousands of amperes
(3) hundredths of an ampere
(4) hundreds of amperes
(5) millions of amperes

A Leyden jar is a kind of
(1) static machine
(2) electroscope
(3) condenser
(4) electrophorus
(5) conductor

If a glass rod is rubbed with silk, the rod
(1) loses electrons
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In a coil the resistance to the flow of current due to the frequency of the alternating current is known as
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The fact that a hot filament in a partial vacuum emitted electrons was first observed by
(1) Faraday
(2) Oersted
(3) Einstein
(4) Edison
(5) DeForrest

When electrons flow through a triode, one of the following is not true
(1) the plate has high positive voltage
(2) the cathode must be heated
(3) the grid is positive with respect to the cathode
(4) the grid is positive with respect to the plate
(5) the cathode is negative with respect to the plate

47. If a transformer has ten turns in its primary and one hundred turns in its secondary
(1) secondary current is 100 times the primary current
(2) secondary volts are 10 times the primary volts
(3) secondary volts are 1/10th of the primary volts
(4) amperes increase
(5) volts decrease

48. Which of the following is essential to these devices: telephones, loudspeakers, television receivers, generators, motors and doorbells
(1) potentiometers
(2) reactance
(3) condensers
(4) fields
(5) electron tubes

49. Which of the following is not true of the electron
(1) it is a negative charge of electricity
(2) it moves freely on a dialectric
(3) it is smaller in size than a hydrogen atom
(4) it is part of all matter
(5) it is present in positively charged bodies

50. The secondary emission at the plate of an electron tube
(1) consists of positive charges
(2) disappears when the plate warms up
(3) is minimized by the suppressor
(4) is controlled by the screen grid
(5) is eliminated by a coated cathode

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SELECT THE BEST ANSWER

, Which of the following is not a property possessed by all matter
(1) density
(2) elasticity
(3) inertia
(4) volume
(5) mass

, In order to balance a 100 lb. boy at a distance of 12 ft. from the balancing point of a see-saw, a 75 lb. boy must be at a distance of
(1) 9 ft.
(2) 6 ft.
(3) 13.5 ft.
(4) 16 ft.
(5) 10 ft.

, A 500 gram frictionless car is at rest on a horizontal surface. A horizontal accelerating force of 1000 dynes acts upon it. The acceleration in cm. per second per second produced is
(1) 1/2
(2) 1/4
(3) 1
(4) 2
(5) 4

, A pulley system has an ideal mechanical advantage of 4. Theoretically, to raise 500 grams, it requires an effort of
(1) 125 grams
(2) 200 grams
(3) 2000 grams
(4) can't tell unless the distance is given
(5) can't tell unless we are told how many pulleys in the system

, The work output can never equal the work imput of a machine because
(1) the mechanical advantage would be less than one
(2) as imput increases, efficiency decreases
(3) at least half the imput is used to overcome friction
(4) the ratio of effort distance to resistance distance is always greater than the ratio of resistance to effort
(5) as imput increases, output decreases

106. Which of these is the best example of kinetic energy
(1) a box of Wheaties
(2) a gallon of fuel oil
(3) a student sitting in class
(4) a paratrooper jumping
(5) a parked car

107. Which of the following is the best example of both potential and kinetic energy
(1) a gallon of fuel oil
(2) a ton of coal
(3) a burning building
(4) a box of Wheaties
(5) a parked car

108. A weight is hanging on a string; you pick up the weight and drop it. The weight breaks the string. This is an example of
(1) inertia
(2) potential energy
(3) kinetic energy
(4) mass
(5) a push or a pull

109. Assuming no friction in a set of pulleys, an effort of 24 pounds lifts a resistance of 120 pounds through a distance of 3 feet. This means that the effort must have travelled
(1) 3 feet
(2) 15 feet
(3) 5 feet
(4) 8 feet
(5) 40 feet

110. If a machine has a distance ratio of 5/3, then
(1) the theoretical mechanical advantage will be greater than 5/3
(2) the theoretical mechanical advantage will be equal to 5/3
(3) the theoretical mechanical advantage will be less than 5/3
(4) the ratio of resistance to effort is 5/3
(5) the actual mechanical advantage is 5/3

111. When we pay the power company for kilowatt-hours we are paying for
(1) power
(2) force
(3) work
(4) 1000 watts of electricity
(5) watts

112. The period of a simple pendulum depends upon
(1) its length alone
(2) its mass alone
(3) the length of its arc
(4) the mass and the length
(5) the mass and the length of arc

113. The theoretical mechanical advantage of an inclined plane is
(1) the angle of elevation
(2) ratio of resistance to effort
(3) the height of the plane
(4) mechanical advantage plus friction
(5) ratio of length to height

114. We report percentage errors because
(1) people think in percentages
(2) it is legal to do so
(3) it is easier to compare errors
(4) it is easier than absolute error
(5) decimals are easier than fractions

115. The smallest scale marking usually found on meter sticks is
(1) the micron
(2) the centimeter
(3) the kilometer
(4) the millimeter
(5) the decimeter

116. Materials such as frosted glass which allow the passage of some light but through which we cannot see are
(1) transparent
(2) translucent
(3) opaque
(4) electro-luminescent
(5) fluorescent

117. When a pure blue light is passed through a pure red filter
(1) no light is transmitted
(2) red light is transmitted
(3) blue light is transmitted
(4) red and blue are transmitted
(5) purple light is transmitted

118. Water can be made chemically pure
(1) boiling
(2) filtering
(3) sedimentation
(4) chlorination
(5) distillation

119. If a concentrated solution has mor solute added to it, it will be
(1) saturated
(2) supersaturated
(3) dilute
(4) precipitated
(5) not necessarily any of these

120. Charles' law deals with changes in
(1) absolute temperature
(2) absolute temperature and volum
(3) pressure and volume
(4) pressure and temperature
(5) volume only

121. Which of the following operates because of the unequal expansion o metals
(1) thermostat
(2) mercury barometer
(3) aneroid barometer
(4) hydrometer
(5) hygrometer

122. If the difference between reading wet and dry bulb thermometers is small, the relative humidity is
(1) high
(2) low
(3) close to zero
(4) close to 100
(5) can't tell with this informatic

23. Water in a kettle is heated principally by
(1) conduction
(2) convection
(3) radiation
(4) agitation
(5) thermodynamics

24. Which of the following will expand at the same rate when heated
(1) liquids
(2) solids
(3) gasses
(4) liquids and gasses
(5) liquids and solids

25. 0^{o} Fahrenheit is approximately equal to a reading of
(1) 32^{o} centigrade
(2) -18^{o} centigrade
(3) 273^{o} Kelvin
(4) 273^{o} centigrade
(5) 0^{o} centigrade

26. If the temperature of an enclosed gas remains constant and its volume is doubled, its pressure will be
(1) 4 times as much
(2) 2 times as much
(3) the same
(4) 1/2 as much
(5) 1/4 as much

27. Which of the following is used to measure relative humidity
(1) thermostat
(2) mercury barometer
(3) aneroid barometer
(4) hydrometer
(5) hygrometer

28. If a gas is cooled to absolute zero,
(1) its volume will be zero
(2) its pressure will be high
(3) its molecules will have no elasticity
(4) its molecules will have no kinetic energy
(5) its specific heat will be zero

129. Storm jackets are lined with fluffy material because this material is
(1) a poor radiator of heat
(2) a good radiator of heat
(3) of low specific heat
(4) a good conductor of heat
(5) a poor conductor of heat

130. The desert nomads wear loose woolen clothing because it
(1) absorbs perspiration
(2) doesn't absorb perspiration
(3) is a good heat conductor
(4) is a poor heat conductor
(5) is a poor heat radiator

131. The first law of thermodynamics states that
(1) heat cannot of itself pass from a hot to a cold body
(2) heat cannot of itself pass from a cold to a hot body
(3) heat engines are not very effecient
(4) energy cannot be changed without some loss
(5) the energy of heat processes is always preserved

132. The astronomical unit is
(1) a light year
(2) a million miles
(3) a parsec
(4) mean distance of earth from sun
(5) 186,000 miles

133. A monistic theory of cosmogony which postulates a continuous creation of hydrogen as the building blocks of matter was advocated by
(1) Whipple
(2) Hoyle
(3) Chamberlain
(4) Kant-Laplace
(5) Einstein

134. An eclipse of a star by the moon is called
(1) lunar eclipse
(2) occulation
(3) perigee
(4) apogee
(5) gibbous

135. The approximate length of an astronomical unit is
(1) a thousand miles
(2) 186 thousand miles
(3) a million miles
(4) 93 million miles
(5) over a billion miles

136. The path of the sun, the moon, and the planets among the stars is known as
(1) epicycle
(2) eccentric
(3) zenith
(4) ecliptic
(5) perturbation

137. The time at which the sun's rays reach the tropic of Cancer and start moving south is called
(1) spring
(2) vernal equinox
(3) autumnal equinox
(4) winter solstice
(5) summer solstice

138. When a magnetic compass is shielded from nearby magnetic substances, it will always point
(1) to the true north pole
(2) to the northwest
(3) to the magnetic north pole
(4) to the northeast
(5) not necessarily to any of these

139. An iron bar is suspended by a string. The south pole of a magnet attracts one end of the bar. That end of the bar is
(1) the south pole of a magnet
(2) the north pole of a magnet
(3) either unmagnetized or a north pole
(4) either unmagnetized or a south pole
(5) unmagnetized

140. Which of the following is <u>not</u> true of lines of force
(1) they show the direction of the magnetic field
(2) they never cross one another
(3) they repel each other
(4) they start at the south pole and end at the north pole, not going through the magnet
(5) their number determines the strength of the field

141. Two pith balls 2 centimeters apart are both charged with a glass rod which has been rubbed with silk. The distance between them is then increased to 4 centimeters. As a result they will
(1) attract with twice the force
(2) attract with four times the force
(3) attract with 1/4 the force
(4) repel with 1/4 as much force
(5) repel with four times the force

142. In an alternating current circuit, the combined effect of resistance and reactance is called
(1) inductance
(2) reluctance
(3) transconductance
(4) impedance
(5) frequency

If we wish to rectify a current, we must use a
(1) diode to change a.c. to d.c.
(2) diode to change d.c. to a.c.
(3) pentode to give a non - pulsating d.c.
(4) tetrode to give 60 cycles
(5) suppressor to smooth out the a.c.

Which of the following will produce a useful electric current
(1) rubber rubbed with fur
(2) glass rubbed with silk
(3) two strips of the same metal in a salt solution
(4) a wire cutting an electric or magnetic field
(5) a coil of wire wound around a magnet

In a simple electric cell having zinc and copper electrodes immersed in hydrochloric acid, the electricity is produced by
(1) the copper
(2) the zinc
(3) the hydrochloric acid
(4) the copper and the zinc
(5) none of these

Two pith balls initially two centimeters apart are charged with a rubber rod that has been rubbed with fur. They are then moved until they are six centimeters apart. As a result they will
(1) attract with three times as much force
(2) repel with three times as much force
(3) attract with nine times as much force
(4) repel with 1/9 as much force
(5) attract with 1/9 the force

147. If a voltmeter is connected in series with a circuit being tested, it will
(1) give a false reading
(2) read amperes
(3) burn out
(4) read volts
(5) read ohms

148. An electronic circuit differs from a purely electrical circuit in that
(1) it has a backward flow of electrons
(2) it has no resistance
(3) electrons flow through wires
(4) electrons flow through gasses
(5) there is no difference

149. One of the following does <u>not</u> affect the resistance of a wire
(1) length
(2) temperature
(3) voltage
(4) type of metal used
(5) cross-section

150. Three resistances of 2, 4 and 6 ohms respectively are connected in a parallel circuit. The total e.m.f. of the circuit is 24 volts. The current registering in an ammeter at the terminals of the circuit will be
(1) 12 amperes
(2) 6 amperes
(3) 22 amperes
(4) 2 amperes
(5) 11 amperes