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AUTHOR Mitias, R. G. E.
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ABSTRACT

Described is a follow-up study to identify the objectives for science teaching measured by a sample of current editions of four standardized physics achievement tests. The methodology employed for the study is described. The findings of the study pointed to several changes. Among these were the attention given, at least by some of these tests, to (1) the application of general physics principles in terms of explanation, interpretation and solution of related mathematical problems; and (2) the interpretation of graphs and data and formulating main ideas presented in graphical data. It is the author's opinion that, while changes in curricula, methodology, etc. seem to have dominated these last 20 years, evaluation instruments seem to trail far behind. (Author/EB)

WHAT BEHAVIORAL OBJECTIVES DO PHYSICS TESTS ACTUALLY MEASURE: PART II.

by

R.G.E. Mitias, Ph.D.
Associate Professor of Education
Ohio University
Athens, Ohio

National Association for Research
in Science Teaching

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Introduction and Rationale

Much emphasis is given to identification and specification of objectives of science teaching. Increasing attention is focused on development of behavioral objectives which are pertinent to science. The ever increasing list of publications on the subject at least demonstrates a pre-occupation with the subject. This may be taken as an index of the significance and value which science educators and teachers attach to it.

Most science teachers and educators are aware of the basic objectives which are generally accepted for science teaching. Those who work with curriculum development and materials are also continuously striving to provide experiences which are congruent with the stated objectives.

Students, at the high school level (as well as at the doctorate level), strive to achieve those ends which are used for their evaluation. Teachers, consciously or subconsciously, emphasize those concepts and objectives which happened to be dominant on an evaluating instrument. This instrument may be a standardized achievement test or other type of test. Smith and Tyler stressed the effect of teachers' conception of achievement tests on their teaching as follows:

> Teachers, too, are frequently influenced by their conception of the achievement tests used. If these tests are thought to emphasize certain points, these points will be emphasized in teaching even though they are not included in the plan of the course.[1]

It follows, then, that objectives which teachers stress most in their teaching and the ones which students attempt to achieve in their learning -- are those objectives which are included on achievement tests. If this premise prevails, then it is extremely significant for science teachers, scientists and educators to scrutinize, thoroughly, various science achievement and other evaluation instruments in terms of the objectives which which these instruments measure.

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Probably just as much - if not more - attention need to be given to assessment and analysis of achievement tests as it is geven to the identification and statement of objectives for science teaching. Tyler emphasized this need early as follows:

> A satisfactory test for examination in <u>any subject</u> is an instrument which gives us evidence of the degree to which students are reaching the objectives of the subject. One major defect of typical examinations has been the fact that these examinations have given evidence with reference to only a limited number of objectives....Hence, a fundamental task in constructing achievement tests is to make certain that the important objectives of the subject and the course are adequately measured....Tests need to be constructed for <u>each</u> of the important objectives of the course.[2]

More recently, Mager re-emphasized Tyler's point regarding the organic relationship between tests and course objectives. Mager states:

> Tests and examinations are the mile points along the road to learning and are supposed to tell the teacher and the student the degree to which both have been successful in their achievement of the course objectives.[3]

Focusing on science teaching, Boeck made suggestions regarding improvements in evaluating science teaching and achievements through improved achievement tests. Boeck states:

> Evaluation of teaching and achievement in science may be characterized as being centered on measurement of acquired factual information. Unfortunately, this is continuing in spite of our knowing that this type of outcome is short-lived at best and of less lasting value than some of the accepted objectives of science instruction irrespective of future plans of the pupils. Examination techniques and tests to measure achievement in these objectives, including the ability to use the methods of science, do reflective thinking, use problem solving techniques, and the degree to which scientific attitudes are developed and employed by pupils: need development, validation and standardization.[4]

The Committee on Rethinking Science Education recognized the need for establishing evaluation in terms of the stated objectives of science teaching. The Committee stressed the functional relationship between the two components as follows:

> Objectives indicate the nature of the educational endeavor and denote the direction it should take... Evaluation should be in terms of all the goals that are set for the teaching process...[5]

The above review demonstrates that a functional relationship need to be established between all the accepted goals of teaching science and the instruments which are used for evaluation of science teaching. It is the main thesis of this paper that no matter how elaborately or extensively we state objectives or how much we value them, such objectives will receive little, if any, attention from science teachers and students unless these objectives are included clearly and intentionally in the evaluation instruemtn. In most cases these evaluation instruments happen to be standardized achievement tests.

The Problem

Few studies focused attention on what physics tests actually measure in terms of the generally accepted objectives for science teaching. In 1949 Burke reported on a study of critical thinking in physics as measured by physics tests. Burke concluded his findings on a discouraging note:

> ...tests for critical thinking are needed. Unfortunately, there is lack of experience in the field of testing for critical thinking, and one should not hope for too rapid progress.[6]

In 1971, Mitias reported a study on various objectives for science teaching which were measured by a sample of standardized physics achievement tests. The tests used were mostly constructed in the late 1950's and early 1960's. Mitias' findings showed that the tests primarily emphasized objectives such as recall of factual knowledge, recall of physics principles, and interpretation and mathematical application of these principles. Very little attention was given - in most of the tests - to evaluation of other objectives such as how to draw conclusions from given data, how to interpret graphs, how to test hypotheses, or how to assess attitudes toward superstitions or suspending judgment.[7]

The Purpose of this Study:

The present study is a follow-up on on the earlier one done by the author (Mitias, 1971). The primary purpose of this investigation was to identify the objectives, for science teaching, which are measured by a sample of the most current editions of four standardized physics achievement tests.

More specifically, this study attempted to answer the following questions:

1. What behavioral/specific objectives of science teaching does a sample of current standardized physics achievement tests measure?

2. How do these tests compare with one another with regard to the emphasis they give to an identified list of science teaching objectives?

3. How does this sample of current standardized physics achievement tests compare, generally, with the findings of the earlier study, reported by the author, regarding measurement of various objectives of science teaching?

Methodology

I. Development of the Instrument:

a. A thorough study of the literature was conducted to identify the major objectives of science teaching which could be measured through a paper-and-pencil type test. Eleven general objectives were identified and selected on the basis of their frequency and consistent appearance in the literature on science education*

b. The eleven general objectives identified in 1 above were then stated in specific behavioral terms. Literature related to this area was thoroughly explored with attention given primarily to specific behavior related to physics**

c. The following "check-list" was then developed as the instrument for the analysis of the tests. This instrument is composed of all eleven general objectives and their sub categories - which are stated in specific/behavioral terms***
These objectives follow:

1. <u>Knowledge of Factual Information:</u>
The solution of the test items requires the student to:
1.1 Recall specific facts of physics
1.2 Recall general physical principles
1.3 Define common technical terms used in physics texts and publications
1.4 Recall certain historic facts or events in physics

* See selected bibliographic material related to this area.

** See selected bibliographic material related to this area.

*** This instrument was used in an earlier study reported by the author (Mitias, 1971).

2. <u>Application of Physics Principles</u>:
   The solution of the test items requires the student to:
   2.1 Interpret or explain physics principles which have been given
   2.2 Interpret or explain physics principles which the student recalls
   Explanation was used to mean, also, solution of physics-mathematical problems which required use of physical principles.

3. <u>Ability to Identify Problems</u>:
   The solution of the test items requires the student to:
   3.1 Identify problematic situations
   3.2 Differentiate between facts and problems
   3.3 Differentiate between problems and hypotheses
   3.4 Isolate single major idea of a problem
   3.5 State a problem
   3.6 Evaluate problems in terms of personal and social needs.

4. <u>Ability to Analyze Problems</u>:
   The solution of the test items requires the student to:
   4.1 Pick out and/or define key words as a means of better understanding of the problem(situation)
   4.2 Identify the relationship(s) of minor problems to the major one
   4.3 Identify the basic assumptions of the problem.

5. <u>Ability to Collect Information</u>:
   The solution of the test items requires the student to:
   5.1 Differentiate authoritative and non-authoritiative (reliable and less reliable) sources of information
   5.2 Criticize articles, editorials, etc.
   5.3 Select data which are pertinent to a problem
   5.4 Arrange and/or make graphs of data

6. <u>Ability to Test Hypotheses</u>:
   The solution of the test items requires the student to:
   6.1 Select an hypothesis, from a list of hypotheses, which most adequately explains given data
   6.2 Determine the accordance (agreement) of an hypothesis with the data
   6.3 Determine the adequacy of an hypothesis in explaining the problem
   6.4 Recognize the tentative nature of an hypothesis.

7. <u>Ability to Interpret Graphs and Data</u>:
   The solution of the test items requires the student to:
   7.1 Obtain specific information from graphical material
   7.2 State relationships as tentative generalizations which may serve as hypotheses.
   7.3 Criticize inferences drawn from data by recognizing whether an inference is an implication of the data, unrelated to the data, or contradicted the data
   7.4 Formulate the main ideas presented in the data

8. Attitude Toward Superstition:
   The solution of the test items requires the student to:
   8.1 Assess belief or non-belief in charms or signs of good or bad luck
   8.2 Identify statements that are not definitions, are not verifiable by observations or do not have implications which are verifiable by observations, and are not mathematical or logical propositions
   8.3 Interpret "mysterious" and "strange" situations by natural causes

9. Attitude to Suspend Judgment:
   The solution of the test items requires the student to:
   9.1 Criticize faulty deductive reasoning
   9.2 Delay taking a decision or passing judgment if data were insufficient or inadequate
   9.3 Identify exaggerations in judgment or conclusions based on given data
   9.4 Demand observational evidente or other pertinent data before accepting statements as facts

10. Ability to Draw Conclusions:
    The solution of the test items requires the student to:
    10.1 Accumulate and relate tested evidence which supports a conclusion
    10.2 Evaluate conclusions in relationship to assumptions set up for the problem
    10.3 Apply conclusions to new situations

11. Ability to Differentiate Between Various Components in Thought Processes:
    The solution of the test items requires the student to:
    11.1 Distinguish between an hypothesis and a conclusion
    11.2 Differentiate between a conclusion and a principle
    11.3 Isolate a fact from a broader principle

II. Selection of the Physics Achievement Tests:

Four high school standardized physics achievement tests were selected for this study. Selection was based on the following:

a. All are paper-and-pencil type tests
b. All are widely used
c. All publishers granted permission for use in the study
d. All are latest editions of the tests used in an earlier study.

The four tests included in this study are:

1. Dunning-Abeles Physics Test, Form E, Harcourt, Brace & World, Inc., New York, 1967.

2. Tests of the Physical Science Study Committee, Form F, Educational Testing Service, Princeton, N.J., 1967.

3. Every Pupil Scholarship Test, Bureau of Educational Measurement Kansas State Teachers College, Emporia, Kansas, 1970.

4. Minnesota High School Achievement Examination, Form EH(Rev.), Test No. 17, American Guidance Service, Circle Pines, Minnesota, 1968.

This last test is the newest edition of the one used in the earlier study under the title: Midwest High School Achievement Examination, Form G, Educational Publishers, Inc., 1960.

III. Analysis of Test Items:

Each item on each of the four tests was analyzed in terms of the "check-list" developed in I. above. This process of analysis attempted to identify the minimum behavioral processes needed by a hypothetical high school student to answer the test item correctly. The analysis was done in the following format:

Test item	general objective(s)	specific/behavioral objective
1	1,2	1.1, 1.3, 2.2

IV. Organization of the Data:

a. The specific/behavioral objectives which were involved in the answer of each test item were identified. The general objectives were then listed whenever at least one specific/behavioral objective of that general objective was included in the solution. This was done for each test item on each test.

b. The frequencies of each behavioral objective and of each general objective were calculated on each test. The percentages were also calculated in relationship to the total number of items on each of the four tests.

c. Results of the analysis were put in tables regarding each general objective and its behavioral components. A table was made to compare the frequency and percentage of each of the behavioral objectives on each of the four tests. This was also done to compare each of the present four tests with its parallel earlier edition. For economy's sake, however, the results are included here in two summary tables. Table I presents the findings of this study, and answers questions 1 and 2 in the problem statement. Table II presents the findings of the earlier study. Comparison between tables I and II would answer question 3 in the statement of the problem.

R.G.E. Mitias
Ohio University
Athens, Ohio
NARST, 1975

TABLE I: Frequencies and Percentages of the General and Specific/Behavioral Objectives as Measured by Four Physics Tests - (Mitias, 1975)

Test Objectives	Dunning-Abeles (50)		PSSC (80)		Every Pupil (50)		Minnesota (122)	
	Freq	%	Freq	%	Freq	%	Freq	%
1	50	100	80	100	50	100	122	100
1.1	46	92	76	95	46	92	107	87.7
1.2	44	88	76	95	34	68	65	53.3
1.3	50	100	80	100	48	96	112	91.8
1.4	1	2	--	0.0	--	0.0	--	0.0
2	38	76	72	90	27	54	59	48.4
2.1	--	0.0	2	2.5	--	0.0	1	0.8
2.2	38	76	70	87.5	27	54	58	47.6
3	1	2	43	53.7	5	10	15	12.3
3.1	1	2	0	0	5	10	8	6.6
3.4	1	2	43	53.7	5	10	15	12.3
3.2, 3.3, 3.5, 3.6*	--	0.0	--	0.0	--	0.0	--	0.0
4	--	0	46	57.5	--	0.0	3	2.46
4.1	--	0.0	0	0	--	0.0	2	1.64
4.2	--	0.0	46	57.5	--	0.0	1	0.82
4.3*	--	0.0	--	0.0	--	0.0	--	0.0
5**	--	0.0	--	0.0	--	0.0	--	0.0
6	--	0.0	8	10	--	0.0	--	0.0
6.1	--	0.0	7	8.7	--	0.0	--	0.0
6.2, 6.3, 6.4*	--	0.0	2	2.5	--	0.0	--	0.0
7	18	36	57	70	3	6	--	0.0
7.1	13	26	44	55	3	6	--	0.0
7.4	13	26	55	68.6	3	6	--	0.0
7.2, 7.3*	--	0.0	--	0.0	--	0	--	0.0
8, 9, 10	--	0.0	--	0.0	--	0.0	--	0.0
11**	--	0.0	--	0.0	--	0.0	--	0.0

* These specific/behavioral categories of the general objectives received no frequencies or 0.0%

** These general objectives and all their behavioral categories received no frequencies in any of the tests used.

R.C.E. Mitias
Ohio University
Athens, Ohio
NARST, 1975

TABLE II: Frequencies and Percentages of the General and Specific/Behavioral Objectives as Measured by Four Physics Tests - (Mitias, 1971)

Test Objective	Dunning (75)		N.Y. PSSC (78)		Every Pupil (85)		Midwest (Minnesota) (97)	
	Freq	%	Freq	%	Freq	%	Freq	%
1	75	100	78	100	85	100	97	100
1.1	72	96	71	91	21	24.7	37	38.1
1.2	68	90.6	69	88.4	36	42.[illegible]	46	47.4
1.3	75	100	78	100	85	100	97	100.0
1.4	1	1.25	--	0.0	2	2.5	2	2.01
2	16	21.3	21	26.9	23	27.0	27	27.8
2.1	7	9.3	8	10.03	1	1.15	2	2.1
2.2	9	12.0	13	16.87	22	25.85	25	25.7
3	10	13.3	24	30.8	6	7.0	9	9.3
3.1	2	2.7	8	10.3	2	2.4	5	5.2
3.4	9	12.0	21	26.9	6	7.1	9	9.3
3.2, 3.3, 3.5, 3.6*	--	0.0	--	0.0	--	0.0	--	0.0
4	4	5.3	17	21.8	5	5.9	5	5.2
4.1	1	1.3	13	16.6	5	5.9	3	3.1
4.2	--	0.0	12	15.4	1	1.2	1	1.03
4.3	3	3.8	11	14.1	1	1.2	2	2.06
5	2	2.7	4	5.1	--	0.0	2	2.06
5.3	2	2.7	4	5.1	--	0.0	1	1.03
5.4	--	0.0	--	0.0	--	0.0	1	1.03
5.1, 5.2*	--	0.0	--	0.0	--	0.0	--	0.0
6	5	6.7	3	3.8	--	0.0	1	1.03
6.1	4	5.3	1	1.3	--	0.0	1	1.03
6.2	1	1.3	1	1.3	--	0.0	--	0.0
6.3	--	0.0	1	1.3	--	0.0	--	0.0
6.4*	--	0.0	--	0.0	--	0.0	--	0.0
7	--	0.0	15	19.2	--	0.0	--	0.0
7.1	--	0.0	15	19.2	--	0.0	--	0.0
7.4	--	0.0	10	12.8	--	0.0	--	0.0
7.2, 7.3*	--	0.0	--	0.0	--	0.0	--	0.0
8, 9, 10 11**	--	0.0	--	0.0	--	0.0	--	0.0

* These specific/behavioral categories of the general objectives received no frequencies or 0.0%.

** These general objectives and all their behavioral categories received no frequencies in any of the tests used.

Findings

Findings of this study are presented, in a condensed manner, in Table I. Table II is presented here, from an earlier study, for comparative purposes as indicated above. The major findings of this study may be summarized as follows:

1. General objective #1: Knowledge of factual information (physics) and its behavioral components (1.1, 1.2, 1.3) are heavily emphasized by all four physics achievement tests, as Table I indicates. Behavioral component 1.4 : recall certain historic facts or events in physics, however, seems to receive no attention in any of these tests. The results of the present study with respect to general objective #1 seem to be consistent with the earlier study regarding these findings when comparing Tables I and II.

2. General objective #2: Application of physics principles and its behavioral component 2.2 seem to rank second in terms of what these tests emphasized. There is much less attention given to behavioral component 2.1 (interpret or explain physics principles which have been given). The emphasis seems to focus on interpretation and/or solution of physics problems which require recall of general physics principles (2.2) as Table I indicates. Comparing Tables I and II shows an apparent increase in the emphasis given to this objective in the current edition of the tests as compared to the earlier edition. It seems that all four tests have increased remarkably in this general objective. The PSSC test seems to have increased the most followed closely by the Dunning-Abeles test.

3. General Objective #3: Ability to identify problems and its behavioral component objective 3.4 was emphasized only by the PSSC test, and to a lesser degree by the Minnesota Achievement test. Behavioral components 3.2, 3.3, 3.5 and 3.6 did not seem to be measured by any of the tests. The results here seem to agree with those of the earlier stydy. The major exception seems to be the degree to which the PSSC test emphasize behavioral component 3.4 (isolate single major idea of a problem) which increased from 26.9% to 53.7% in the present edition.

4. General objective #4: Ability to analyze problems, and its behavioral components seemed to receive little attention from these tests with the exception of the PSSC test. Tables I and II show that this general objective increased from 21.8% to 57.5% in the present study. One, however, must point out that this increase focused mainly on behavioral objective 4.2 to the exclusion of other behavioral components. Other tests seem to

have maintained about the same level of attention given to this objective or even declined slightly.

5. General objective #5: Ability to collect information and its behavioral components 5.1, 5.2, 5.3, and 5.4 were not measured by any of the tests used in this study as Table I indicates. Comparison between Tables I and II show that whatever little the earlier tests have measured seemed to have been eliminated in the more current editions.

6. General objective #6: Ability to test hypotheses and its behavioral components 6.1 and 6.2 appeared to be measured to a small degree (10%) only by the PSSC test. The rest of the tests ignored it completely. Comparing Tables I and II show that the PSSC test improved slightly on measuring this objective while the other tests seem to have abandoned any attempt toward such measurement.

7. General objective #7: Ability to interpret graphs and data, and its components 7.1 and 7.4 were emphasized much more in this study by the tests with the exception of Minnesota High School Achievement Examination. Comparing Tables I and II shows PSSC with 70% of the items requiring this skill compared to 19.2% in the earlier edition and Dunning-Abeles with 36.1% of the items requiring some skill in this area compared to 0.0% in the earlier edition.

8. Examining Table I (as well as Table II) we see that four general objectives 8-11 and their behavioral components as listed on the instrument were not measured by any of the tests used. This seems to hold true on the earlier study as well as the present one. The general objectives which were neglected on these tests are: Attitude toward superstition, Attitude to suspend judgment, Ability to draw conclusions, and Ability to differentiate between various components in thought processes.

General Comments

This study has attempted to identify behavioral objectives which current editions of four standardized achievement tests measure. It also attempted to compare the findings with those of a previous study of earlier editions of these tests in order to identify any changes in the emphases which these tests place on various science teaching objectives.

The findings of this study pointed to several changes. Among these were the attention given, at least by some of these tests, to (a) the application of general physics principles in terms of explanation, interpretation and solution of related mathematical problems, (b) the interpretation of graphs and data and formulating main ideas presented in the graphical data.

Major attention of the tests seems to focus almost in every item on knowledge of factual information in physics. This included recall of facts,general physical principles and definition of technical physics terms.

Very little or no attention was given to several objectives of science teaching. Among these were the following general objectives:
Ability to collect information, ability to test hypotheses, attitude toward superstition, attitude to suspend judgment, ability to draw conclusions, and the ability to differentiate between various components in thought processes (ie. hypotheses, conclusions, facts, and principles).

Conclusion

It is encouraging to observe a change in some physics achievement tests toward more emphasis on other objectives beside that of recall of factual information. However, this change seems to be less than universal. In addition, one still observes the lack of evaluation of science teaching objectives which have been considered vitally important among science educators. This seems to hold true for physics tests developed in the last twenty years. While changes in curricula, methodology, etc. seem to have dominated these twenty years, evaluation instruments seem to trail far behind. If the earlier premise of this study that individuals, including students, strive to achieve the ends which are used as criteria for their evaluation (often teacher made tests are patterned after standardized instruments) holds true, then one expects high school students to give greatest attention to the objectives measured by these achievement tests. This would happen no matter what other objectives one may state for the curriculum. Thus, it becomes imperative that in order to achieve other vital objectives for science teaching that these objectives be included on evaluation instruments; in this case standardized achievement tests. Otherwise, results of curriculum and methodological changes would be incidental and students' achievement along these objectives would be very difficult to assess.

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