AN ANALYSIS OF NINTH GRADE PUPILS' UNDERSTANDING OF THE SCIENCE PROCESSES

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The purpose of this study was to determine the attained pupil understanding of certain science processes from a random selection of ninth grade pupils. The Test of Science Processes was administered to an Introductory Physical Science experimental group and to a traditionally-taught control group to determine the students' attainment of the science processes.

Computer programs were used to determine means for the tables and the data were analyzed by use of the t test. It was found that the traditional science-taught courses are as effective as the Introductory Physical Science program when compared with the Test of Science Processes.

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CHAPTER I

INTRODUCTION

During the past two decades we have seen the development and implementation of many new science education programs. Additional research is needed in order to evaluate the effectiveness of these new programs. In many cases, the evaluation of these new programs was done by the program designers using tests that they had constructed.[1,2,3,4] Decisions concerning implementation of new programs need to be based on all available evidence. The purpose of this research is to provide some of this needed evidence.

The following quotation shows the general need for research in science teaching. This was written in 1938 and is as true today as when it was written.

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[1]Sixth Report of the International Clearinghouse On Science And Mathematics Curricular Developments 1970 Edited under The Direction of J. David Lockard (Maryland: American Association for the Advancement of Science and the Science Teaching Center, 1970) p. 305.

[2]Leopold E. Klopfer and William W. Cooley, Use of Case Histories in the Development of Student Understanding of Science and Scientists (Cambridge, Massachusetts: Harvard University, 1961).

[3]William W. Williams, "An Experimental Investigation of Individualized Instruction in the Teaching of Quantitative Physical Science" (Durham, North Carolina: Duke University Department of Education, Unpublished Ed.D. dissertation, 1969).

[4]Raymond E. Thompson, "IPS Achievement Test," A Progress Report: Introductory Physical Science, Physical Science II. Ed. IPS Group (Newton, Mass.: Education Development Center, 1969) p. 14.

> ...It is generally recognized that there is much confusion in the field of science teaching, both about the purposes which this instruction should serve and the most effective procedures for realizing these purposes. Society has changed so rapidly that educators have found it difficult to devise educational programs adequate to meet the new conditions of living and their accompanying changes in human thinking and action.[5]

One of the major objectives of science teaching has been to provide science pupils with an understanding of the science processes. The purpose of this study will be to evaluate a selected group of ninth-grade science pupils' understanding of and their ability to use certain science processes. For the purposes of this study science processes are defined as the methods used by students of science and by scientists to perform scientific experiments and to solve science related problems.

Definition of the Problem

This study compares two groups of science pupils' abilities and skills in the science processes as measured by the *Test of Science Processes*.[6] Tannenbaum designed this test specifically for use in the junior high school science program. The *Test of Science Processes* evaluates the science pupils' ability to use the following science processes: observing, comparing, classifying, quantifying, measuring, experimenting, inferring, and predicting.[7]

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[5]Progressive Education Association, *Science in General Education*, A Report of the Committee on the Function of Science in General Education (New York: D. Appleton-Century Co., 1938), p. 4.

[6]Robert S. Tannenbaum, "The Development of The Test of Science Processes," (Ed.D. dissertation Columbia University, 1968), University Microfilms, Inc., Ann Arbor, Michigan.

[7]*Ibid.*, p. 4.

The Sample Studied

The ninth-grade science pupils in this study were selected from two different groups. The first, or experimental group, consisted of pupils who studied Introductory Physical Science (IPS)[8], a laboratory-oriented science program, and the second, or control group, consisted of pupils who studied a more conventional type of physical science program. The experimental group consisted of 278 males and 300 females for a total of 578 pupils. The control group consisted of 172 males and 180 females for a total of 352 pupils.

The research completed and reported here is a continuation of research done by Sheppard in 1974.[9] The same experimental and control groups were used and the testing was completed as part of his research.

The general hypothesis tested is as follows: Pupils studying the IPS program will score significantly higher on the Test of Science Processes. The test scores of the two groups were analyzed for differences in total scores and for differences in subgroup scores which were a measure of the attainment in each of the science processes. These analyses are described and reported in Chapter III.

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[8] IPS Group of Educational Services Inc., Introductory Physical Science, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1967.

[9] Moses M. Sheppard, "The Effect of Two Different Methods of Instruction," unpublished research reported at a seminar, October, 1974, East Carolina University, Greenville, North Carolina.

CHAPTER II

REVIEW OF THE RELATED LITERATURE

This research report is designed to evaluate student attainments in certain science processes. With this general research objective the related literature is reviewed in two broad areas, as follows: (1) the historical development of science education objectives and (2) the specific literature related to the teaching of the science processes and their evaluation.

Science education was first introduced in the American secondary school program in the academies in the period between 1751 and 1872. The objectives at this time were primarily descriptive, utilitarian, and religious as expressed by Benjamin Franklin.[1] With the establishment of the high school in Boston in 1821, the science curriculum included very little or no laboratory work and only a few demonstrations. Learning of facts was emphasized. Pupils were to acquire information that was of practical value. There was no emphasis on college entrance requirements; however, there was emphasis on meeting the functional needs of the young people. In addition, many educators felt that school programs should be developed to help pupils adapt to their environment.[2]

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[1] John S. Richardson, Science Teaching in Secondary Schools, (Englewood Cliffs, N.J.: Prentice-Hall, 1957), p. 10.

[2] Ibid., p. 15.

In the early 1900's there was a trend to the teaching of science in order to meet the needs of the pupils for their practical purposes as well as for college preparation. During this period, many educators felt that the school programs should include more laboratory work in well-equipped laboratories with reference books and laboratory entry books for the pupils. It was felt that field excursions should be plentiful and that pupils should be taught to think instead of simply to memorize material. Until this time memorization of factual material had been stressed.

During the 1930's the science teaching objectives began to emphasize scientific thinking, as is illustrated by the authors of the Thirty-first Yearbook of the National Society for the Study of Education. They proposed that science teaching should be organized around certain broad principles of science and that understanding of these should lead to the formation of generalizations. Science educators also began to emphasize the importance of teaching for scientific attitude.[3]

In 1942 the National Committee on Science Teaching published a report on the objectives of science teaching. This report proposed that conservation, safety, and consumer education be added to the science teaching objectives.[4]

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[3]The Thirty-first Yearbook of the National Society for the Study of Education, A Program for Teaching Science (Chicago: The University of Chicago Press, 1932), p. 43.

[4]National Committee on Science Teaching, Redirecting Science Teaching in the Light of Personal-Social Needs, (Washington: The American Council of Science Teachers, 1942).

The report of the Harvard Committee emphasized the importance of science in general education. Effective thinking and the making of relevant judgments were emphasized, both are considered important science processes.[5]

The Educational Policies Commission[6] proposed that students practice scientific inquiry to develop a knowledge of the experimental method.

In the Forty-sixth Yearbook of the NSSE[7], the general objectives of science teaching were listed as:

1. functional information or facts
2. functional concepts
3. functional understanding of principle
4. instrumental skills
5. problem-solving skills
6. attitudes
7. appreciation
8. interest.[8]

By the late 1950's the objectives of science teaching as they appeared in the educational literature had changed little over the past twenty-five years. The sciences had become more unified, and science was being

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[5]Report of the Harvard Committee, General Education in a Free Society, (Cambridge, Mass.: Harvard University Press, 1945).

[6]Educational Policies Commission, Education for All American Youth, (Washington, D. C.: National Education Association, 1944), pp. 130-133.

[7]National Society for the Study of Education, The Forty-sixth Yearbook, Part I Science Education in American Schools, Ed. Nelson B. Henry (Chicago: The University of Chicago Press, 1947), pp. 28-29.

[8]Ibid.

taught for understanding and for science as an enterprise. Problem solving was stressed in the teaching of science. The teaching of the scientific method was expanded to include both the teaching of the science methods and how these methods could be used in the solutions of science related problems. Hurd, in 1960, referred to science as a process and said that science should be taught as inquiry.[9]

> A process of inquiry involves careful observation, seeking the most reliable data, and then using rational processes to give order to the data and to suggest possible conclusions or further research. At higher levels of achievement the student should be able to establish relationships from his findings, and in turn to make predictions about future observations.[10]

Hurd further recognized that the scientific processes and the knowledge produced cannot be assumed to be ends in themselves. Young people need to understand that society depends upon scientific and technological achievements and that science is a basic part of our modern living. They also need to acquire skills and abilities which enable them to assume responsibilities for expanding their own learning. These skills and abilities are referred to in the literature as the science processes.[11]

In 1961, the AAAS held three conferences concerning the needs for new materials in the elementary and junior high school.[12]

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[9] Paul DeH. Hurd, "Science Education for Changing Times," Rethinking Science Education, The Fifty-ninth Yearbook of the National Society for the Study of Education, Part I (Chicago: The University of Chicago Press, 1960), pp. 34-35.

[10] *Ibid.*, p. 35.

[11] *Ibid.*, pp. 33-34.

[12] Arthur H. Livermore, "The Process Approach of AAAS Commission on Science Education," Journal of Research in Science Teaching, IV (1964), pp. 271-282.

As an outgrowth of the 1961 conferences, AAAS established a commission of science education which had as its purpose the development of science curriculum materials for the elementary and junior high school. The resulting program was entitled Science--A Process Approach.[13] This program listed the following as science processes: (1) observing, (2) classifying, (3) measuring, (4) communicating, (5) inferring, (6) predicting, (7) recognizing space/time relationships, (8) recognizing number relations, (9) formulating hypotheses, (10) making operational definitions, (11) controlling and manipulating variables, (12) experimenting, (13) interpreting data, and (14) formulating models.[14]

In the series of materials referred to as Science--A Process Approach the pupils are given opportunity to improve their skills in the use of the science processes.[15]

Renner and Stafford[16] composed a list of major processes of science in 1972. These were:

(1) Problem identification and hypothesis formation.

(2) Experience has proved that the data which experiments and observations provide in one instance would be repeated if the experiment or observation were repeated.

(3) Beliefs which arise from the interpretation of data must be verified.

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[13] Ibid., p. 273.

[14] Ibid., pp. 273-274.

[15] Ibid., pp. 272-274.

[16] John W. Renner and Don G. Stafford, Teaching Science in the Secondary School, (New York: Harper and Row, 1972), pp. 33-35.

(4) The hypothesis, when verified, is a general solution to the problem.[17]

Livermore[18], in 1964, identified the processes of science as follows:

(1) Observing
Identifying objects and object properties. Proceeds to the identification of changes in various physical systems, the making of controlled observations, and the ordering of a series of observations.

(2) Classifying
Development begins with simple classification of various physical and biological systems, and progresses through multi-stage classification, their coding and tabulation.

(3) Measuring
Beginning with the identification and ordering of lengths, development in this process proceeds with the demonstration of rules for measurement of length, area, volume, weight, temperature, force, speed, and a number of derived measures applicable to specific physical and biological systems.

(4) Predicting
For this process, the developmental sequence progresses from interpolation and extrapolation in graphically presented data to the formulation of methods for testing predictions.

(5) Inferring
Initially, the idea is developed that inferences differ from observation. As development proceeds, inferences are constructed for observation of physical and biological phenomena, and situations are constructed to test inferences drawn from hypotheses.

(6) Experimenting
This is the capstone of the "integrated" processes. It is developed through a continuation of the sequence for controlling variables, and includes the interpretation of accounts of scientific experiments, as well as the activities of stating problems, constructing hypotheses, and carrying out experimental procedures.[19]

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[17]Ibid.

[18]Authur H. Livermore, "The Process Approach of the AAAS Commission on Science Education," Journal of Research in Science Teaching, Vol. 2, Issue 4, 1964, pp. 271-282.

[19]William K. Esler, Teaching Elementary Science, (Belmont, California: Wadsworth Publishing Co. Inc., 1973), pp. 59-63.

Tannenbaum[20] defines science processes as follows: "Processes" are ways of doing things. In their field, scientists have to make careful observations in order to interpret correctly what they are observing. Frequently, a scientist must be able to use numbers and figure measurements. He also must be able to set up an experiment and read results correctly.[21]

Today scientists and educators seem to be in a general agreement that as a result of secondary school science education, the pupil should:

1. Acquire and be capable of demonstrating increased knowledge and understanding of the facts, concepts, and principles of science.

2. Show improvement in his ability to use his increased understanding of the facts, concepts, and principles of science by applying the methods of scientists in the solution of problems.

3. Be capable of demonstrating an increase in his ability to think critically.

4. Demonstrate improvement in his understanding of the scientific enterprise, the scientists, and the methods and the aims of science.[22]

Most of the new science programs developed in the 1960's had as a general objective the attainment of the science processes. This was reflected in the written objectives as well as in the types of curricula materials developed. Some of the common elements of these new courses and their objectives are:

1. Less emphasis is placed on application and technology than in the traditional courses.

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[20]Robert S. Tannenbaum, "The Development of the Test of Science Processes," Journal of Research in Science Teaching, VIII (1972), pp. 123-136.

[21]Ibid.

[22]Moses M. Sheppard, The Relation of Various Teacher and Environmental Factors To Selected Learning of Ninth-Grade Science Pupils, (Ph.D. Dissertation, The Ohio State University, 1966), pp. 23-24.

2. More emphasis is placed on abstractions, theory and basic science.

3. Discovery-type laboratory is emphasized.

4. Subject matter is treated more rigorously.

5. There is frequent use of quantitative techniques.

6. New concepts in subject matter are presented.

7. There is a need for up-grading of teacher competency for successful teaching of the course, with a variety of teaching aids to supplement the course.

8. Courses are constructed for good teaching and learning practices along with many clever innovations.

9. Students are given opportunities to explore, along with flexibility, so that the average as well as the below average may succeed in the framework of the course.

10. Science is presented in a favorable light so that the student is able to understand what a scientist is and what he does in our society.[23]

It should be noted from the above that most new science programs propose that their program will teach the pupils to use the science processes.

Haber-Schaim[24] has proposed that a study of the Introductory Physical Science program should provide the pupils with:

1. a knowledge of physical science subject matter content,

2. experience in making observations,

3. experience in developing basic laboratory skills,

4. a knowledge of how to apply elementary mathematics to experimental results,

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[23]Robert B. Sund and Leslie W. Trowbridge, Teaching Science by Inquiry In the Secondary School, (Columbus, Ohio: Charles E. Merrill Books, Inc., 1967), pp. 59-60.

[24]Uri Haber-Schaim, "Objectives and Content of the Course", Introductory Physical Science--A Progress Report, (Newton, Mass.: Educational Development Center, Spring, 1969) pp. 2-3.

5. experience in correlating abstract ideas to concrete situations,
6. knowledge of how to judge orders of magnitude,
7. experience in making approximations, and
8. experience in judging what is important.[25]

There have been numerous attempts to assess elementary school pupils' ability to use the science processes; for example, Ransom[26], in 1968, did a study to determine the differences between pupils studying under teachers using Science--A Process Approach and pupils studying under teachers not using Science--A Process Approach. He found no significant differences between the two groups of pupils.

Price[27] investigated the transfer of science processes in the elementary school. He experimented to determine if children in the elementary school who have been trained to manipulate objects and materials with their hands for the purpose of empirically gathering data use these same processes when they are confronted with objects or apparatus that present a problem outside the classroom, even if they have not been trained to do so deliberately.[28]

The results of this test were based on observation techniques that the Los Angeles County Science Project had developed in 1961-1963.[29]

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[25] Ibid.

[26] Wayne Edwin Ransom, "Effect of Science--A Process Approach on Creative Thinking and Performance in Selected Processes of Science in the Second Grade." Ph.D. thesis, Syracuse University, 1968 (Dissertation Abstracts).

[27] Lamar Price, "An Investigation of the Transfer of an Elementary Science Process." Ed.D. thesis, University of Southern California, 1968 (Dissertation Abstracts).

[28] Ibid.

[29] Ibid.

The conclusions were:

(1) The gifted children showed no higher incidences of empirical data gathering process or their transfer than children of "normal" range of I.Q.

(2) The process under observation did not transfer to a new situation.

(3) Boys tend to manipulate objects to gain information relatively more frequently than girls.[30]

In 1971, Damewood[31] conducted an experiment to evaluate the physical science course for the prospective elementary teacher in terms of competences attained in the processes of science. The analyses of this experiment showed that:

(1) There was a possibility for students to increase their process competence by performing laboratory exercises of their own choosing.

(2) There was no particular process of science achieved after a single exposure to that process in a laboratory exercise.

(3) There was an increase in the pupil's competence in the processes of using numbers, communication, inferring and interpreting data when the laboratory exercises were developed around some content-based concept.[32]

Burns[33] developed a field test in 1972 and validated a usable, objectively-scored test of integrated process skills of science as was defined by the Commission of Science Education of the American Association for the Advancement of Science.

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[30] Ibid.

[31] Judith C. Damewood, "Evaluation of a Physical Science Course for Propsective Elementary Teachers in Terms of Competence Attained in the Processes of Science." Ed.D. Thesis, Auburn University, 1971, (Dissertation Abstracts).

[32] Ibid.

[33] Sandre Flynn Burns, "The Development of a Test to Measure Performance of Elementary Majors on the American Association for the Advancement of Science's Integrated Process Skills of Science." Ph.D. Thesis, University of Connecticut, 1972, (Dissertation Abstracts).

The five integrated process skills of science are formulating hypotheses, defining operationally, controlling variables, interpreting data, and experimenting. This particular instrument's greatest use along with other findings was to assess differences between groups of students in their attainment of these science processes.[34]

> The experimental instrument discriminates consistently among tests on the basis of developed ability in the integrated process skills of science as shown by significantly higher scores on the experimental instrument of high achieving students in a science method course which encouraged development of the process skills of science, and by the significant differences in performance on the experimental instrument of science professors, science majors, undergraduates and the elementary education undergraduates.[35]

At Arizona State University in 1972, Ralph Rogers[36] did a comparative study of a laboratory-centered approach and a group discussion approach of the science processes. The Processes of Science Test, the Watson-Glaser Critical Thinking Appraisal, and A Scale to Study Attitudes Towards College Courses were administered as pre-tests, and these tests were used as post-tests at the end of the course.

Of the several conclusions, it was specifically noted that there was no significant difference in achievement levels and attitudes toward science courses. However, there was a signficiant difference in the critical thinking ability favoring the group which had received the laboratory investigation program.[37]

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[34] Ibid.

[35] Ibid.

[36] Ralph Rogers, "A Comparison of Two Methods of Science Instruction in a College General Studies Program: A Lab Centered Approach and a Group Discussion Approach." Ed.D. Thesis, Arizona State University, 1972, (Dissertation Abstracts).

[37] Ibid.

John Woodburn[38] did a study in 1970 at Columbia University with general science students and their correlation between in-school and out-of-school science experiences. In this study he used factors such as the home environment, variations in the general, social, and economic conditions prevailing within the student's home, sex difference, 4-H club participation, and Scout membership. Consideration was also given to the pupil's interest in reading science books, the amount of school science instruction they received prior to the ninth grade, and with the pupil's intelligence.[39]

The Read General Science Tests were given to this group of pupils as they entered the ninth grade. Upon completion of the ninth grade an equivalent form of the same test was given. According to the author, provisions were made to acquire an estimate of gain in science information that may be ascribed to sheer maturity.

Woodburn feels that --

> ...the importance of this study hinges on determining whether the content and level of experiences offered the students in the ninth-grade General Science should be adjusted according to the extent to which these students have participated in other experiences prior to being enrolled in the course.[40]

Williams[41] in 1969 conducted an experimental investigation on ninth

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[38]John Woodburn, "Relationship Between the Science Information Possessed by Ninth Grade General Science Students and Certain School and Out of School Science Experience." Research in Science Education 1953 through 1957, Ed. by Elizabeth Phelan Lawlor, (New York: Columbia University, 1970), p. 41.

[39]Ibid.

[40]Ibid.

[41]William W. Williams, "An Experimental Investigation of Individualized Instruction in the Teaching of Quantitative Physical Science." (Durham, North Carolina: Duke University, Department of Education, Unpublished Ed.D. dissertation, 1969).

grade science pupils to determine the effectiveness of the individualized instruction versus group instruction in the teaching of Quantitative Physical Science (QPS). He constructed and validated a comprehensive test in basic physical science which he used as a criterion for the research. He used a control group and an experimental group both using QPS, and a reference group who studied a different course in physical science.

> It was concluded that, so far as achievement on semester examination, standardized tests, and semester grades were concerned, individualized instruction was more effective than group instruction for most students.[42]

In 1968, Tannenbaum developed the Test of Science Processes, the particular instrument used in this research. Its development and validation is described in his dissertation.[43]

The test instrument consisted of 96 multiple-choice (five choice) questions requiring a total testing time of 73 minutes. The test requires the use of a projector to show 35mm color slides in order to include questions which involve color. Administered to 3,673 public junior high school students from New York, the total test yielded a reliability of .91, using the Kuder-Richardson Formula 20. Reliabilities of the eight subgroups of the test, each dealing with one of the science processes, ranged from .26 to .82, also using the Kuder-Richardson Formula 20. Tannenbaum established the test validity by the technique of "validation by experts."[44]

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[42]Ibid.

[43]Robert S. Tannenbaum, "The Development of the Test of Science Processes", (Ed.D. dissertation, Columbia University, 1968).

[44]Ibid.

In 1972, Butzow and Sewell[45] conducted a study in the Union Street Junior High School in Bangor, Maine, where the Test of Science Processes was given to 127 eighth grade students, of which 92 pupils completed all the instruments used. The students were divided according to ability, into four groups ranging from 22-25 students in each group.

These divisions were called 8^1 with an Otis-Lennon Mental Ability Test (OLMAT) mean of 95.0, 8^2 OLMAT mean I.Q. of 102.0, 8^3 OLMAT mean I.Q. of 109.5, and 8^4 OLMAT mean I.Q. of 118.5. The students were given the TSP as a pre-test prior to studying IPS. After studying the first five chapters of IPS, the students were given TSP as a post-test.[46]

The results indicate a difference in the changes of the 8^4 group with respect to the following processes: observing, classifying, inferring, and predicting. The 8^3 group shows a difference in comparing, classifying, and experimenting. 8^2 groups show a difference in classifying, measuring, and inferring while the 8^1 group showed a difference in quantifying.[47]

The analysis revealed some significant improvement in all four group divisions. Division 8^1 showed the least improvement while the division 8^4 showed the most improvement. Also--

> ...there were many differences by division in the specific process categories in which significant improvements were shown. Therefore, some divisions were much more advanced in their ability to use science processes at the start of IPS.[48]

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[45]John W. Butzow and Leyton E. Sewell, "An Investigation of Introductory Physical Science Using the Test of Science Process." Journal of Research in Science Teaching, Vol. 9, No. III (1972), pp. 267-270.

[46]Ibid.

[47]Ibid., p. 268.

[48]Ibid., p. 270.

To summarize the objectives of science teaching, there has been a gradual evolution of science teaching objectives since the beginning of science education in this nation. The present objectives include the understanding and use of science processes in addition to acquiring and using knowledge in the solution of problems. Several studies have been done to determine the pupils' ability to use the science processes, but there has been no attempt to evaluate the students' ability to use the science processes as a means of evaluating a particular method of instruction. The latter is the subject of this research.

CHAPTER III

THE RESEARCH DESIGN AND ANALYSIS OF DATA

The purpose of this study was to evaluate a selected group of ninth-grade science pupils' understanding of and ability to use certain science processes. A basic assumption is that the Test of Science Processes will evaluate the pupils' knowledge of and understanding of the science processes.[1]

The basic design of this research was to choose two groups of pupils who had studied a one-year program in ninth-grade physical science. The experimental group had studied IPS, a laboratory-oriented science course. The control group had studied a more conventional type of physical science course. This experimental design is described by Campbell and Stanley as the Static-Group Comparison. "This is a design in which a group which has experienced X is compared with one which has not, for the purpose of establishing the effect of X."[2] These two groups were administered the Test of Science Processes during May, 1973.

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[1]Robert S. Tannenbaum, The Development of the Test of Science Processes, (Ed.D. dissertation, 1968, Columbia University), University Microfilms, Inc., Ann Arbor, Michigan.

[2]Donald T. Campbell and Julian C. Stanley, "Experimental and Quasi-Experimental Designs for Research on Teaching," Handbook of Research on Teaching, ed. N. L. Gage, (Chicago: Rand McNally and Company, 1963), p. 182.

Except for the two different methods of instruction, the two groups were assumed equivalent. The pupils' Otis-Quick Scoring Mental Ability Test[3] scores were used to test the assumption of equivalent groups. The following table describes the two groups.

TABLE 1

DESCRIPTION OF THE TWO GROUPS[4]

	Number of Pupils	Mean Otis I.Q.	t	p
IPS Group	578	100.68 S.D. 14.84	1.52	.10
Control Group	352	102.50 S.D. 15.00	1.10	.20
Total Group	930	101.62		

Sheppard analyzed the pupils' Test of Science Processes scores to determine if there were any differences between the two groups. He used the analysis of variance with I.Q. as a covariance.

[3] Arthur S. Otis, Manual of Directions for Gamma Test, (New York: Harcourt, Brace and World, Inc., 1954).

[4] Moses M. Sheppard, "The Effect of Two Different Methods of Instruction," unpublished research reported at a seminar, October, 1974, East Carolina University, Greenville, N. C.

The results of his analysis are shown in the following table.

TABLE 2

TSP AND SEX, GROUP, AND I.Q. EFFECTS[5]
ANALYSIS OF COVARIANCE TABLE

Source	NDF	Residual Sums of squares	Mean Square	F Ratio	Level of significance
I Effect (Sex)	1	296.3	296.3	2.25	.25
J Effect (Group)	1	69.2	69.2	.53	*
K Effect (I.Q.)	3	1356.9	452.3	3.43	.05
I X J	1	13.6	13.6	.10	*
I X K	3	35036.8	11678.9	88.68	.001
J X K	3	1915.3	638.4	4.85	.01
I X J X K	3	-32978.5	-10992.8	83.47	.001
Within	893	117602.9	131.7		
Total	908	123312.7			

*Not significant

As can be seen from Table 2, after adjusting for I.Q. differences, the analysis of the group effect revealed no significant differences in the test scores between the experimental and control groups. The interaction analysis of the Group times I.Q. (J x K) effect was significant at the .01 level even after the adjustment for the I.Q. effect.

[5] *Ibid.*

As analysis of the cell means adjusted for the I.Q. effect revealed no significant differences between the adjusted scores of the experimental group and the control group of the first three lower I.Q. quartiles. The highest I.Q. quartile performed better in the experimental group with a level of significance of $p < .01$.[6]

This research has analyzed the Test of Science Processes subgroup scores which according to Tannenbaum[7] reveal evidence of pupils' knowledge and understanding of specific science processes.

The null hypotheses tested here for each of the science processes are as follows: (1) There are no significant differences between the test scores of the two groups and the published norms on the Test of Science Processes. (2) There are no significant differences between the mean test scores of the experimental and the control groups of this research.

The tests of the hypotheses to determine the differences between the means of the groups were done by using standard deviation estimated from the sample data. The test statistic was[8]

$$t = \frac{X - u1}{s/\sqrt{n}}$$

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[6] Ibid.

[7] Tannenbaum.

[8] B. J. Winer, Statistical Principles In Experimental Design. (New York: McGraw-Hill, 1962), p. 20.

The pupils' scores on test items related to the science process of observing were analyzed and compared with norms published by Tannenbaum.[9] The following table shows the results of this analysis.

TABLE 3

ANALYSIS OF GROUP SCORES AND THE PROCESS OF OBSERVING

Group	Mean Scores	t	p
Experimental	4.15	7.84	<.01
Control	4.17	7.09	<.01
Tannenbaum[10]	4.83 S.D. 1.75		

The data in Table 3 reveals that neither the experimental nor the control group did as well on the process of observing as Tannenbaum's experimental group. When comparing the experimental group with the control group, no significant differences were observed between the two groups on the science process of observing. Therefore, hypothesis (1) must be rejected with respect to the process of observing and hypothesis (2) must be accepted.

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[9]Tannenbaum. The Development of the Test of Science Processes.

[10]Ibid.

The pupils' scores on test items related to the science process of comparing were analyzed and compared with the norms published by Tannenbaum.[11] Table 4 shows the results of this analysis.

TABLE 4

ANALYSIS OF GROUP SCORES AND THE PROCESS OF COMPARING

Group	Mean Scores	t	p
Experimental	3.04	8.37	<.01
Control	3.09	6.94	<.01
Tannenbaum[12]	3.50 S.D. 1.11		

These results of the process of comparing reveal that neither the experimental nor the control group did as well on the process of comparing as Tannenbaum's[13] experimental group. In comparing the experimental with the control group, no significant differences were found. Therefore, hypothesis (1) must be rejected and hypothesis (2) must be accepted with respect to the science process of comparing.

[11] Ibid.

[12] Ibid.

[13] Ibid.

The pupils' scores on the test items related to the science process of classifying were analyzed and compared with the norms published by Tannenbaum.[14] The results of this analysis are found in Table 5.

TABLE 5

ANALYSIS OF GROUP SCORES AND THE PROCESS OF CLASSIFYING

Group	Mean Scores	t	p
Experimental	6.55	12.47	<.01
Control	6.79	9.63	<.01
Tannenbaum[15]	7.97 S.D. 2.30		

These results of the process of classifying reveal that neither the experimental nor the control group did as well as Tannenbaum's[16] experimental group on the process of classifying. In comparing the experimental with the control group, no significant differences between the experimental group and control group were found. Therefore, hypothesis (1) must be rejected and hypothesis (2) must be accepted with respect to the science process of classifying.

[14] _Ibid._

[15] _Ibid._

[16] _Ibid._

The pupils' scores on the test items related to the science process of quantifying were analyzed and compared with the norms published by Tannenbaum.[17] The results of this analysis are found in Table 6.

TABLE 6

ANALYSIS OF GROUP SCORES AND THE PROCESS OF QUANTIFYING

Group	Mean Scores	t	p
Experimental	7.01	14.01	<.01
Control	7.74	6.86	<.01
Tannenbaum[18]	8.55 S.D. 2.22		

These results of the analysis of the scores for the process of quantifying reveal that neither the experimental group nor the control group did as well as Tannenbaum's[19] experimental group. In comparing the experimental with the control groups of this research, the control group did better than the experimental group with a confidence level of $p < .01$. Therefore, hypothesis (1) and (2) must be rejected with respect to the process of quantifying.

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[17]Ibid.

[18]Ibid.

[19]Ibid.

The pupils' scores on the test items related to the science process of measuring were analyzed and compared with the norms published by Tannenbaum.[20] The results of this analysis are found in Table 7.

TABLE 7

ANALYSIS OF GROUP SCORES AND THE PROCESS OF MEASURING

Group	Mean Scores	t	p
Experimental	12.12	2.36	<.01
Control	12.15	2.07	<.025
Tannenbaum[21]	12.66 S.D. 4.63		

These results of the analysis of the scores for the process of quantifying reveal that neither the experimental group nor the control group did as well as Tannenbaum's[22] experimental group. In comparing the experimental with the control groups of this research, there were no significant differences. Therefore, hypothesis (1) must be rejected and hypothesis (2) must be accepted with respect to the science process of measuring.

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[20] Ibid.

[21] Ibid.

[22] Ibid.

The pupils' scores on the test items related to the science process of experimenting were analyzed and compared with the norms published by Tannenbaum.[23] The results of this analysis are listed in Table 8.

TABLE 8

ANALYSIS OF GROUP SCORES AND THE PROCESS OF EXPERIMENTING

Group	Mean Scores	t	p
Experimental	4.04	-1.72	<.05
Control	4.25	-3.57	<.01
Tannenbaum[24]	3.87 S.D. 2.00		

These results of the analysis of the scores for the process of experimenting reveal that both the experimental and control groups did better than Tannenbaum's[25] experimental group. In comparing the experimental with the control group of this research, the control did better than the experimental group with a confidence level of $p < .025$. Therefore, hypotheses (1) and (2) must be rejected with respect to the science process of experimenting.

[23] Ibid.

[24] Ibid.

[25] Ibid.

The pupils' scores on the test items related to the science process of inferring were analyzed and compared with the norms published by Tannenbaum.[26] The results of this analysis are listed in Table 9.

TABLE 9

ANALYSIS OF GROUP SCORES AND THE PROCESS OF INFERRING

Group	Mean Scores	t	p
Experimental	5.15	.242	*
Control	5.15	.23	*
Tannenbaum[27]	5.18 S.D. 2.50		

*Not Significant

These results of the analysis of the scores for the process of inferring reveal that there are no significant differences. Therefore, both hypotheses (1) and (2) must be accepted with respect to the science process of inferring.

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[26] Ibid.

[27] Ibid.

The pupils' scores on the test items related to the science process of predicting were analyzed and compared with the norms published by Tannenbaum.[28] The results of this analysis are found in Table 10.

TABLE 10

ANALYSIS OF GROUP SCORES AND THE PROCESS OF PREDICTING

Group	Mean Scores	t	p
Experimental	3.48	-1.12	<.20
Control	3.52	-1.46	<.10
Tannenbaum[29]	3.38 S.D. 1.80		

The results of the analysis of the scores of predicting revealed that both groups did better than Tannenbaum's[30] experimental group, but the differences were not significant. There were no significant differences between the experimental and control groups of this research. Therefore, hypotheses (1) and (2) must be accepted with respect to the science process of predicting.

The summary of these analyses of the pupils' scores of the Test of Science Processes and recommendations are presented in Chapter IV.

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[28] Ibid.

[29] Ibid.

[30] Ibid.

CHAPTER IV

The review of the related literature in Chapter II revealed that teaching for an understanding of the science processes is now an accepted objective of science teaching. This research has analyzed pupils attainment in the science processes as measured by the Test of Science Processes.

Sheppard[1] analyzed the total scores on the Test of Science Processes of the same sample as this research and found no significant differences between the experimental group and the control group after adjustments had been made for the I.Q. In this study, the Test of Science Processes scores were analyzed for each specific science process by test item analysis. The results of these analyses have been given in their relevant places within the text of Chapter III. In this chapter, the major conclusions and recommendations pertaining to this study will be summarized.

Major Conclusions

The results of this study indicate that neither the experimental nor the control group performed as well on the Test of Science Processes as did Tannenbaum's[2] experimental group.

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[1]Moses M. Sheppard, "The Effect of Two Different Methods of Instruction," unpublished research reported at a seminar, October, 1974, East Carolina University, Greenville, North Carolina.

[2]Robert S. Tannenbaum, The Development of the Test of Science Processes, (Ed.D. dissertation, 1968, Columbia University), University Microfilms, Inc., Ann Arbor, Michigan.

The analysis of the pupils' subtest scores of the Test of Science Processes revealed that of the eight subtest scores, each one representing attainment in a particular science process, the pupils in this research study did significantly better than Tannenbaum's[3] experimental group on only one of the science processes. This was the science process of experimenting. In comparing the experimental group with the control group of this research there were no significant differences between the pupils' scores on the specific science processes except on the science process of experimenting and quantifying; here the control group did significantly better than the experimental group.

These analyses of the pupils' scores on the Test of Science Processes indicated that with regard to the pupils' attainment of the science processes that both methods of instruction are equally effective.

Recommendations

There is a definite need for additional studies of this type. A telephone conversation with the author of the test instrument revealed that there has been no research using his instrument except for Butzow and Sewells' research which was reported in Chapter II of this study.

The author of this research feels that specific units need to be developed with a design of teaching for the science processes explicitly. In order for this research to be more effective with a course designed just for the teaching of the science processes, it is essential that the instrument be administered to the pupils as a

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[3] Ibid.

pre-Test of Science Processes and a post-Test of Science Processes. This method of pre-testing and post-testing would reveal any previous knowledge of the science processes that the pupils may have already attained.

Further research is needed to identify other possible factors that influence what pupils learn as a result of their science instruction, such as their attitude toward science.

The test instrument is of poor reproduction quality and the photographs and diagrams are difficult to read and interpret; therefore, the instrument should be reproduced with clarity. The poor quality of the instrument reproduction may help to explain why Tannenbaum's[4] experimental group did better than those of this research group.

In the previously mentioned telephone conversation with Tannenbaum[5] on May 14, 1975, he confirmed that the test instrument is of poor reproduction quality and that he has plans for revision and reproduction of the instrument.

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[4]Ibid.

[5]Ibid.

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