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A study to determine the opinions of educators relative to the inclusion of Wise's physical science principles at the elementary school level

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A STUDY TO DETERMINE THE OPINIONS OF EDUCATORS RELATIVE TO THE INCLUSION OF WISE'S PHYSICAL SCIENCE PRINCIPLES AT THE ELEMENTARY SCHOOL LEVEL

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CHAPTER I

INTRODUCTION

Sciences such as chemistry, physics, and biology have been and always will be advancing and progressing; therefore, science educators have, of necessity, constantly revised their thinking in order to keep up with the advancement of science itself. With the onrushing degree to which science has moved within the past ten years, it has become increasingly necessary to adjust science teaching materials and methods and to proceed with ideas that will be beneficial to man and society.

In the approach to building a course of study, all educators have agreed to the idea of planned objectives; these objectives for science are best expressed in terms of principles.

STATEMENT OF THE PROBLEM

The purpose of this study was to consider a number of physical science principles as developed by Harold E. Wise,[1] for general science education, and their applicability to the elementary school curriculum as determined by elementary

1/Harold E. Wise, A Determination of the Relative Importance of Principles of Physical Science for General Education, Unpublished Doctor's Dissertation, University of Michigan, 1941.

science supervisors and specialists.

The jury chosen for this study was not informed of the fact that these physical science principles had been considered primarily for secondary instruction.

JUSTIFICATION OF THE STUDY

An examination of periodicals, bulletins, and textbooks, regarding the status of instruction in science in the elementary school has revealed that principles suitable for elementary school instruction are not standard. For the past decade, however, surveys and a number of research projects have done much in an attempt to bring about accepted standards for science instruction. Leonelli[1/] in doing research work at Boston University attempted the problem of selection and grade placement of Robertson's[2/] principles of physical science. Of the eighty-one principles involved, both teacher and expert agreed on selection. There appeared to be a great difference of opinion in the matter of grade placement.

1/Renato E. Leonelli, The Selection and Grade Placement of Physical Science Principles in the Elementary School Curriculum, Unpublished Doctor's Dissertation, Boston University, 1952.

2/Martin L. Robertson, A Basis for the Selection of Course Content in Elementary Science, Unpublished Doctor's Dissertation, University of Michigan, 1934.

Many authorities have advocated the teaching of science based upon principles rather than on general facts. One of the earliest writers in this field, and a well known educator, Elliot R. Downing,[1/] said:

> "Two methods of instruction are conceivable in preparing pupils to meet the problematic situations involving scientific knowledge that will arise in their lives: (1) One may list all such problems that occur in the community and make pupils skillful in meeting each, teaching them how to do each specific thing. Or (2) one may give them an understanding of the principles of science that are most often needed to solve such problems and then may drill them in solving problems under such principles. In other words, he may try to make them skillful in solving such problems."

The obstacles to methods are obviously that there are too many specific ideas to be taught, and that the individual's changing environment prove the things learned might not be useful. While the number of specific things of a scientific nature to be done in any situation are exceedingly numerous, the scientific principles involved in them are often relatively few. This has been especially true in regard to the elementary school science program. No new principles have been formulated in the past twenty years, since all new developments have applied to principles known

1/Elliot R. Downing, An Introduction to the Teaching of Science, The University of Chicago Press, Chicago, Ill., 1934, p. 7.

in the past. Downing[1] asserts that: "Principles are nearly universal; specific problems are local in both time and place." The second method, therefore, was more preferable than the first one described above.

Two significant reports of national societies have set forth aims of education. The field of science was no exception, and specific recommendations concerning an organization for courses in science have been made. The Thirty-First Yearbook[2] committee, the first educational group to advocate the teaching of principles as objectives of science teaching, maintained that classroom experiences be provided in the classroom to satisfy one of the general aims of education, namely: Life Enrichment through Participation in a Democratic Social Order. The education of an individual is defined as the effect on his whole behavior that has come from the experiences in which he has participated. A planned program of education is one that provides experiences that will contribute as fully as may be to the attainment of life enrichment.

1/Elliot R. Downing, op. cit., p. 8.

2/A Program for Teaching Science, Thirty-First Yearbook of the National Society for the Study of Education, Part I, Bloomington, Ill: Public School Publishing Co., 1932, p. 42.

The second educational group, the Progressive Education Association,[1/] reiterated the need for reorganization of science teaching in American schools:

> "The purpose of general education is to meet the needs of individuals in the basic aspects of living in such a way as to promote the fullest possible realization of personal potentialities and the most effective participation in a democratic society."

These two reports gave added interest in designing principles of science as objectives of science teaching in all grades.

Gerald S. Craig,[2/] in attempting to organize a pattern of objectives in elementary science listed three pertinent ideas relating science to the child and his environment.

> "(1) Certain objectives that are selected for elementary science should conform to those scientific conceptions, (a) which, when understood, greatly influence the thought reaction of the individual; (b) which have modified thinking in many fields.
>
> (2) Certain objectives that are selected for elementary school science should conform to those goals (information, skills, and habits) in science that are important because of their function in establishing health, economy and safety in private and public life.

1/Commission on Secondary School Curriculum, Science in General Education, D. Appleton-Century Company, New York, 1938. p, 23.

2/Gerald S. Craig, Certain Techniques Used in Developing a Course of Study in Science for the Horace Mann Elementary School, Bureau of Publications, Teachers College, Columbia University, New York, 1927, p. 12.

> (3) Certain objectives that are selected for elementary school science should conform to those facts, principles, generalizations, and hypotheses of science which are essential to the interpretation of the natural phenomena which commonly challenge children."

Since general-objectives, and principles-as-objectives appeared to be the first appraisal of the particular program, it did not necessarily follow that methods employed nor criteria involved necessitated final accomplishment. This was true in character of science scope and sequence in elementary education.

As to what specific science principles should be taught in the elementary schools, there appears to be no general agreement. Present trends appear to favor generalities rather than specific principles. Read and Nelson 1/ expressed this quite adequately:

"Principles are not topics or areas. They are not definitions or labels. They express, in declarative sentences, relationships between things and processes of the real world."

They then list ten observations made by investigators at Boston University concerning principles:

1/John G. Read and Pearl Astrid Nelson, A View of Science Education Review and Forecast, Journal of Education, Volume 141, Number 2, December 1958, Boston University School of Education, pp. 32-33.

(1) The basic generalizations, concepts or principles of science are useful for organizing the variety of experiences found in the real world.

(2) These principles are finite in number, and they have been scientifically and educationally stated in declarative sentences.

(3) There are too many principles which are assigned to the twelve to fourteen years of the school program for their learning to be understood in one or two courses at the secondary school level; further, to leave them to this level would negate younger pupils' high interest in science and to delay pupils' need for explanation of the environment.

(4) They should be taught and learned; i.e., their final acquisition should not be left to chance.

(5) It is certain that many principles require for their understanding the sophisticated maturity which comes from multiple exposures to applications of the principles. They require also immersion in a socio-economic milieu which uses the principles.

(6) It is likely that starting about the second or third year of school there will be certain of these principles which will be needed by a child of <u>whatever maturity and socio-economic background</u> (within reasonable bounds of normalcy of intelligence, but including even deep-rural cultures) for accurate interpretation and classification of the events in his environment.

(7) It is a fact that teachers, textbook writers, and children's encyclopedia editors have to make decisions as to grade-placement of groups of experiences which they hope will finally be seen to be similar and which can be subsumed under a generalization, concept, or principle.

(8) It may be that some relatively simple classroom research will show educators at about what grade levels a principle may be understood.

(9) It is assumed that even with the problem of the varied experience-background of children, if many of the children in a particular grade have been able to profit by experiences which they have had so that they have made progress in understanding a principle, then others in the

group can relatively easily (through demonstrations, simple research, group study, audio-visual materials, and teacher direction) also come to a real operational use of the principle. Briefly, it should be easy enough to supply common experiences to children who lack them to bring them "up-even" with the children in the grade, and so be able to test-and-teach and teach-and-test to the point where no common experiences of these children in this culture will go unrecognized - from then on.

(10) Research seeking to discover the applicability of the nine rubrics above is initially forced to a more precise stage than is desirable. Controls must be set up. Every experimental group must have identical conditions. The experiment should be replicated in many towns and over a bracket of at least two grades."

No conclusive answers have been given concerning this research in elementary science instruction. A study of the theory and practice concept has left little doubt concerning an attempt to assign a more up-dated core of content to the elementary school science program.

SCOPE AND LIMITATION OF THE STUDY

This study presents a partial picture of the degree of acceptance of certain science principles in the elementary school curriculum. It attempts to provide a source of information on current opinions about elementary school science which may be utilized by curriculum builders, science research workers, and textbook writers. It attempts to serve as a pivotal point for growth rather than a defined outcome, and to offer some minute suggestions for balanced programs in science instruction.

No attempt has been made to grade-place the frequency of a particular principle, or to arrange the items in the outline in the order of their importance or in the best order for teaching.

The 272 physical science principles of Wise[1/] used as a basis for this study are commonly considered appropriate for secondary school science education. The reason for the selection of these particular principles was that Wise's study is considered by many authorities to be the most recent, comprehensive and inclusive work in this area. Although many investigators have used lists of physical science principles as bases for secondary science instruction, little has been done in this respect in the area of elementary science.

Other areas in the biological sciences may offer possibilities for investigation since little has been done in the biological science fields to investigate areas of instruction.

Research relative to the reason for the inclusion of certain science principles in the current elementary school science textbooks requires examination at this time.

1/Harold E. Wise, *op. cit.*, p. 1.

DEFINITION OF TERMS USED IN THIS STUDY

A principle is a definite statement of a fundamental truth. It deals with something directly observable as an action, appearance, change or occurence in the field. Since Wise's[1/] principles of physical science have been accepted as a basis for this study, his criteria for a principle must also be accepted. They are:

> "To be a principle, a statement must be a comprehensive generalization describing some fundamental process, constant mode of behavior, or property relating to natural phenomena.
> It must be true without exception within limitations specifically stated.
> It must be capable of illustration.
> It must not be a definition."

Physical science includes for the purpose of this study the sciences of Physics (including Astronomy), Chemistry, and Geology.

SUMMARY OF THE CHAPTER

It is quite evident from the previous research that three factors are relevant in the embodiment of science instruction: the child, the environment in which he participates, and the subject-matter of science.

Educators today are seeking more and more positive results in the accomplishment of learning through each child's ability. To meet the needs of the individual child

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1/Harold E. Wise, op. cit., p. 174.

in science, it is possible that the use of principles as objectives could justify this end.

The environment in which the child participates has advanced so rapidly in the past fifteen years that science educators must keep in constant awareness the ever-increasing demands which society places upon the child. The Age of the Atom, the abundant information developed through the International Geophysical Year, the advent of Sputnik, and man's journey into space, - these are all part of the child's life today.

The modern space age has already left its imprint upon the child in the elementary school. In many cases it has developed in him a high interest and a keen sense of observation for areas in science not known to a child twenty years ago.

It is increasingly apparent that the investigation into physical science principles conducted by Wise[1/] for secondary education more than two decades ago, can no longer be designated for secondary school science alone.

Man and society working in a democracy to achieve greater goals have now extended their sights to seemingly unlimitless bounds.

1/Harold E. Wise, *op. cit.*, p. 1.

CHAPTER II

THE REVIEW OF THE LITERATURE AND RESEARCH

This chapter is composed of three sections. The first discusses the development of science in the curriculum of the elementary school; the second considers certain selected courses of study in elementary school science which may indicate current trends and opinion; the third presents existing research in science principles.

1. The Development of Science in the Curriculum of the Elementary School

To investigate the development of science in the elementary program in its entirety presents a formidable problem, but since the rapid interest and growth in science lies in the post-war period (1945-1962) to the present day, this study has been considered in a two period sequence. The first period will trace the development from its known beginnings to 1945; the second will discuss a more complete review of science during the past seventeen years.

Beginning of science in elementary education. The introduction of science into elementary education appeared in England at the middle of the eighteenth century. The medium was the textbook. The United States science program followed shortly afterwards and little change occurred during the period to 1910. Underhill[1/] reports that by the middle of the nineteenth century, Reverend Thomas Hill suggested that specific areas (mechanics, chemistry, and biology) be taught at each grade level from kindergarten through college.

After 1860, "object teaching" became known through the Oswego movement. Croxton,[2/] in regard to this states: "object lessons possessed the advantage of directness and they tended to replace the rather mechanical memory-method with the use of the various senses in acquiring knowledge." The purpose of object teaching was to develop habits and powers such as observation and attention.

With the growth of industry in the 1870's, a new fervor appeared which increased interest in science. Croxton[3/] states that William T. Harris, the superintendent of schools in St. Louis, Missouri introduced natural science in the curriculum. He may be accredited as being the first educator

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1/Orra E. Underhill, The Origin and Development of Elementary School Science, Scott, Foresmen and Company, Chicago, Illinois, 1941, p. 13.

2/W. C. Croxton, Science in the Elementary School, McGraw-Hill Book Company, Inc., New York, 1937, p. 22.

3/*Ibid*., p. 23.

to realize the importance of science teaching in the elementary schools. His idea was not to make scientists, but rather to develop in pupils the ability to read and to understand with some certainty the many different science areas. Botany, zoology, and physics were treated in their simplest form, and, as the child progressed, more detailed study was involved.

Weller and Caldwell[1/] write that in 1871 Louis Agassiz opened a summer school for teachers interested in science. At this particular time, textbooks were still used as the official curriculum in science education. Louis Agassiz is reported to have been much opposed to such methods. He stressed learning from the materials themselves and was an advocate of the laboratory and the field approach.

Henry Straight, a disciple of Agassiz, and a professor of natural science in the Oswego Normal School began the early introduction of natural science. Robertson[2/] states in this regard: "He, (Straight) saw the insufficiency of object teaching as an educational process. He sought to overcome these defects by correlation of subjects of study

1/Florence Weller and Otis Caldwell, "The Nature Study and Elementary Science Movement," <u>School Science and Mathematics</u>, (October 1933), Volume 33, p. 730.

2/Martin L. Robertson, "Notes on the Growth of Science in the Elementary School," <u>Educational Outlook</u>, (May 1943), Volume 17, pp. 170-172.

.....Was undoubtedly the first to correlate natural science with geography and other subjects in the curriculum."

Many educators of this period felt the insignificant role played by object lessons in science teaching and began to develop guides which would be more useful to the child and to the teacher. Underhill 1/ reports that Wilburs S. Jackman, a graduate of normal school in Pennsylvania and of Harvard University, did much to centralize the thinking process in science teaching. While teaching science in secondary education, he felt the need for better instruction in the elementary schools. He planned an elementary school course and submitted it to his superintendent. This later became a book and a manual for many school systems. In discussing Jackman, Underhill 2/ states:

> "He organized his material in such a way as to stress understandings of significant ideas. His method for selecting content was in terms of the specialized branches of science, aimed at giving a wide overview of all the fields of science. His writings emphasize the need for basing the teaching of science to children on first hand experience."

It appears that much work and research had been done to organize science education. However, a major factor which possibly affected the results of this work was the incapability

1/Orra E. Underhill, op. cit., p. 145.

2/Ibid., p. 145-146.

of properly trained teachers.

From 1890 to 1920 the Nature Study movement came into existence. Cornell University played an important role in this effort through the works of Liberty Hyde Bailey, Anna B. Comstock and John L. Spencer. Bailey lectured, wrote numerous articles and established the Nature Study Quarterly. Comstock's[1] interest can be thus stated:

> "Nature study is.....a study of nature; it consists of simple truthful observations that may; like beads on a string, finally be threaded upon the understanding and thus held together as a logical, harmonious whole. Therefore the object of the nature study teacher should be to cultivate in the children, powers of accurate observation and to build up within them understanding."

In a number of schools throughout the country, the Nature Study movement had great impetus; and for its early measure of success it became acknowledged as the elementary science curriculum. After thirty years, this movement became less popular. Underhill[2] cites five reasons for its departure from the field of study:

> "(1) lack of organization.
> (2) inability of the teacher to carry on the program.
> (3) limitation of Children's capacity to reason.

1/Anna N. Comstock, Handbook of Nature Study, Comstock Publishing Company, Ithaca, New York, 1929, p. 1.

2/Orra E. Underhill, op. cit., p. 171.

(4) extravagant claims for aesthetic and emotional values.
(5) Nature Study was in reality a restricted area of science."

As the century developed, Weller[1/] reports: "Elementary science was a natural outgrowth of Nature Study.....with its emergence about 1925."

Gerald S. Craig[2/] presented a course of study early in the nineteenth Century which established objectives that need not be influential to a particular area, but to the ever increasing needs of the child and his environment. In summarizing the works of Craig, Underhill[3/] states that it was: "The first serious and scientific attempt to define a curriculum that would enable some functional relationship to be seen between purpose and procedure."

The Thirty-First Yearbook,[4/] Part I, written in 1932 served as a guide for the elementary science program from

1/Florence Weller, op. cit., p. 730.

2/Gerald S. Craig, Certain Techniques Used in Developing a Course of Study in Science for the Horace Mann Elementary School, Bureau of Publications, Teachers College, Columbia University, New York, 1927, pp. 11-14.

3/Orra E. Underhill, The Origin and Development of Elementary School Science, Scott, Foresmen and Company, Chicago, Illinois, 1941, p. 220.

4/A Program for Teaching Science, Thirty-First Yearbook of the National Society for the Study of Education, Part I, Bloomington, Ill: Public School Publishing Co., 1932, p. 14.

that period to the beginning of the Second World War. Notable educators contributing to the thought of this period were, Eliot Downing, Gerald Craig, Charles Pieper, Francis Curtis, Florence Billig, Victor Noll, Ralph Watkins, Morris Meister, and Ralph Powers. Ideas and concepts offered to science were thus stated in the Yearbook:

> "Part I of the Thirty-First Yearbook undertook the interpretation of the accumulated results of research in the teaching of science and of relevant concepts in the fields of philosophy and psychology with the aim of developing an integrated program of instruction in science from the primary through the high school years. As formulated by the yearbook committee, this program was directed toward the understanding of the major generalizations of science and the associated scientific attitudes, the graded courses of instruction being organized so as to present 'an increasingly enlarged and increasingly matured development of objectives.' "

The period from 1945 to 1962. It is undoubtedly true that this period has seen more changes in the elementary science curriculum than in any other time in the history of science itself. Stollberg[1/] states in regard to these changes:

> "The years immediately following World War II were marked by a normal amount of educational adjustment. Science teachers strove to keep their courses abreast of new developments in the field and in line with

1/Robert Stollberg, "How Can Teachers Obtain Equipment for Elementary School Science?" California Journal of Elementary Education, Volume 21, November 1952, pp. 4-5.

the evolving needs of a new generation. But
it was nearly after a decade had passed that
a series of events led to an unprecedented
eruption of activity in science instruction."

In a twelve year period the National Society for the Study of Education reviewed science education. The Forty-Sixth Yearbook[1/] Part I, which investigated current issues in science education at the elementary level suggested the adoption of the following ideas:

"(1) The Place of Science in the Education of Children.
(a) development of the abilities of children as individuals to the end that they will be able to secure the maximum of good for themselves.
(b) development of the individual for social responsibility.
(2) Science Education for All of the Nation's Children.
(3) Objectives of Science in the Elementary School.
(a) functional understanding of information, concepts, and principles.
(b) instrumental skills.
(c) elements of scientific method.
(d) scientific attitudes
(4) Defining the Purposes of Science Education in Light of the Nature of the Child.
(a) the child is an investigator.
(b) the child reacts to all aspects of his environment.
(c) the child's imaginative activities contribute to his growth.
(d) the child seeks to participate in planning and carrying out his activities.

1/ Science Education in America, Forty-Sixth Yearbook of the National Society for the Study of Education, Part I, University of Chicago Press, Chicago, Illinois, 1947, pp. 60-73.

(e) the child follows his own individual pattern in developing concepts.
(f) the child learns through doing.
(g) the child learns through seeking to achieve purposes.

(5) The Setting of Science in the Elementary School Curriculum with Trends in Curriculum Development.
(a) meaningfully and socially significant problems.
(b) a flexible curriculum suited to the needs of the children and of the community.
(c) an integral relation to other phases of the program.

(6) Continuity in the Program.
(a) development of wider and deeper meanings.
(b) ability to do broader and more critical planning in solving their problems of living.
(c) acquisition of desired scientific attitudes, appreciations, and interests.

(7) Balance in the Program.
(a) balance in terms of areas of environment.
(b) balance in terms of areas of living.
(c) balance in terms of time and space.
(d) number and length of problems.
(e) balance throughout elementary-school period.

This is probably by far the most comprehensive report undertaken by science educators. The trend appears to take into account the development of science instruction around the child's behavior and the climate of his surroundings. This child-development theme has raised considerable comment from science educators in regard to what constitutes the most effective program.

The progress with which elementary science education has advanced is quite evident from the fact that the National Society for the Study of Education has devoted four Yearbooks which report science education research. The first two Yearbooks were developed in a fifty year period; while the latter two were written in 1946 and 1960 respectively.

The Fifty-Ninth Yearbook, Part I.,[1/] which reviews the literary efforts and research by such notable science educators as Glenn O. Blough, Paul Blackwood, Katherine E. Hill, and Julius Schwartz, employs a pattern of ideas which the authors deem reliable in the establishment of a program in elementary school science instruction. The following areas reported are those developed from their thinking:

"I. Developing Science Programs in the Elementary School.
- A. The Purposes
  - 1. Origins of Purposes.
    - a. the culture and our purposes
    - b. purposes derived from the nature of science.
    - d. unique contributions of science.
    - e. science for all children.
    - f. science for the more able pupils or for those interested in science.

1/ <u>Rethinking Science Education</u>, Fifty-Ninth Yearbook of the National Society for the Study of Education, Part 1, University of Chicago Press, Chicago, Illinois, 1960, pp. 112-135.

2. Our Purposes and Today's General Culture
3. Social Implications.

B. The Program
1. How the Selection of Subject-Matter is Made.
   a. the child.
   b. the environment
   c. the sciences
   d. the total school program.
2. Organizing the Program.
   a. the structure
   b. advantages of structured programs.
   c. the sequence.
3. The Evaluation of the Program
   a. who evaluates?
   b. when and how should evaluation take place?
   c. characteristics of a good elementary science program.

In summarizing, Pruitt,[1] in an address to the National Science Teachers Association restated three major objectives to every course of science at every level as propounded by Dr. Francis Curtis upon his retirement from the field of education:

> "1. To develop a functional understanding of scientific principles. (Such an understanding of a principle is functional when the learner can apply it in everyday problems appropriate to his level of maturity, ability and experience).
>
> 2. To develop in every individual an understanding of, and the ability to use, the elements of scientific method in solving problems that are appropriate, likewise, to his level of maturity, ability and experience.

1/Clarence M. Pruitt, "In an Interview (with) Dr. Francis Curtis," Science Education, Volume 41, p. 371.

3. Through explanation and application of scientific attitudes, to develop these attitudes in every individual to the maximum extent practicable."

2. The Analyses of Certain Selected Courses of Study in Current Elementary School Science

In preparing data, which reflect the views of science educators in attempts to organize programs of science at the elementary school level, there appears to be certain definite divisions in which investigations and opinions may be categorized.

Science in the total school program. Two prime factors for consideration in elementary education are related to the so-called subject-matter programs and those concentrated in child-centered activities. R. Will Burnett[1] in answer to the type of program best to be developed, posed these general questions to be considered in adapting any particular program:

> "What should this and that subject offer? What mastery should be expected at this and that grade level? What sort of child is this and that child? What sort of individuals should our children mature into? What sort of communities, regions, nation and world do we want to live in and build toward?"

The generalizations stated by Burnett had more fruitful

1/R. Will Burnett, Teaching Science in the Elementary School, Rinehart and Co., Inc., New York, 1959, pp. 114-116.

meaning when interpreted as, what is meant in terms of abilities, attitudes and understandings which would reflect the types of human beings which might live with optimum personal satisfaction and positive values in a democratic society.

In the concomitant process from generalizations to specifics, Burnett[2/] further states:

> "A next major step was to consider the sorts of experiences that might help to develop the human beings characterized by the specific abilities, attitudes, and understandings postulated as desirable. These experiences were thought of as life-like experiences or, more properly, as living experiences that might be suitable for habituating children in the behavior patterns thought desirable. They were experiences in living that could be used for increasingly thoughtful growth toward higher satisfaction and stature for each individual child. The whole framework of subject-matter sequences and logically organized content was set aside in favor of educational experiences in the major areas of life activities in which children were engaging as individuals and social participants in a democracy "

Although there appeared to be two ideas related to curriculum incentives, Burnett demanded a third type be given consideration, namely, the cultural epoch approach. His analysis of this approach gave attention at each grade level to some period of time being devoted to human history.

1/*Ibid*., p. 118.

> ".....the scope for any grade level is determined by the total pattern of life of the society of that time. The arts, sciences, social and governmental arrangements, and beliefs of a people are studied under the expectation that such analeses would be helpful in interpreting present life and its problems."

Science in the total school program as suggested by Craig[1] stems from tradition with which other subjects gained their acceptance. He argues:

> "In a democracy the program in the elementary school must be one that is acceptable to the people of that democracy.....If science remains in the elementary-school curriculum in a democracy, it is because it has been accepted by the people and remains acceptable to them."

Tannebaum and Stillman[2] mention the problem of a modern, technical society and the solving of these problems which demand information, attitudes, and behaviors of a scientific nature in which all need to participate. The changing world has a decided role in what the school program should entail. One purpose of the school is to help people understand the universe and to make decisions which affect

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1/Gerald S. Craig, Science for the Elementary School Teacher, Ginn and Company, Boston, Massachusetts, 1958, p. 35.

2/Harold E. Tannenbaum and Nathan Stillman, Science Education for Elementary School Teacher, Allyn and Bacon, Inc., Boston, Massachusetts, 1960, p. 5.

others. Tannebaum and Stillman state: "Citizens need to see the whole world as it is, as it was, and as it can be. And they need to act in such a manner as to ensure the well being of all people. Society has assigned to the schools the task of helping develop such citizens."

Navarra and Zafforoni 1/ discuss this total school situation with a complete new approach. They acknowledge:

> "The reorientation in the elementary-school curriculum is a direct response to an idea emerging from the psychology of learning which recognizes that learning is thinking. This is a simple but very subtle idea fraught with implications: The learning which accrues to the child comes as a direct response to his involvement in the thinking process.
>
> .....Science, which, simple put, is man's attempt to interpret, control, and live effectively within this environment, becomes the "natural" matrix for problem solving situations.
>
> .....Such subjects as reading, writing and arithmetic can be further developed in a meaningful context around this core called science. With continued orientation of the curriculum along these lines, it is conceivable that science will emerge as the dominant subject of the elementary school."

The Fifty-Ninth Yearbook, Part I, 2/ illustrates quite

1/Navarra and Zafforoni, Science Today for the Elementary School Teacher, Row-Peterson and Co., Elmsford, New York, 1960, p. 17.

2/Rethinking Science Education, Fifty-Ninth Yearbook of the National Society for the Study of Education, Part 1, University of Chicago Press, Chicago, Illinois, 1960, pp. 122-23.

precisely the attitude of science to the total school program in many schools throughout the country. It reports:

> "A basic premise underlying the science program is that it should be in harmony with the total program of education. This implies that elementary science is an integral part of the fabric which includes social studies, language arts, music, mathematics, art and health education. Science brings new strength to the elementary schools. Its methods, its approach to problem solving, and its informational content enrich the whole program and give it new scope and depth."

The Science Program. The use of either the incidental or the planned program of instruction in elementary science education has been debated widely. The latter appears to have gained wide support. The Forty-Sixth Yearbook, Part 1,[1/] strongly recommends the development of social behaviors in the elementary schools, and ....."to accomplish this basic purpose a continuous program of science instruction should be developed throughout public school education, based upon a recognition of the large ideas and basic principles of science and the elements of the scientific method."

The need for a structured program (where definite areas in science are studied) is advocated by Pearl A. Nelson,[2/] who suggests that "the program needs to provide for

1/Science Education in America, Forty-Sixth Yearbook, op. cit., p. 73.

2/John G. Read and Pearl Astrid Nelson, op. cit., p. 11.

incidental or current learnings that are important, but the planned experiences, the planned units of work are the bases for an adequate program."

Navarra and Zafforoni[1/] list four guides in the development of science in the elementary school. They are (1) The development of functional information; (2) The development of instructional skills; (3) An understanding of the scientific method; (4) The development of a scientific attitude. They continue:

> "From its very beginning at the kindergarten level, the sequence is based upon a logical order of learning elements within the total content. The successful elementary-school science program is based upon a logical order of learning elements within the total content. The successful elementary-school science program is based on a sequential development, i.e., on a step-by-step pacing of learning elements."

The Fifty-Ninth Yearbook[2/] lists six generalizations which serve well the sequence of elementary science, if the content provides for the growth of children in their understanding of science concepts and principles. They are:

1/Navarra and Zafforoni, op. cit., pp. 22-23.

2/Rethinking Science Education, Fifty-Ninth Yearbook, op. cit., p. 129.

> "(a) the child's view of the world begins with the here and now and extends to the far away and long ago.
>
> (b) the child grows in ability to reason, to generalize, to apply principles, to see cause-and-effect relationships.
>
> (c) as the child develops physically he is able to participate in activities requiring great strength and dexterity.
>
> (d) the child's increasing capacity for comprehending such dimensions as time, distance, speed and direction, or weight may influence sequence.
>
> (e) strong motivation provided by current interests and the special character of the local environment may sometimes outweigh other considerations in the determination of sequence.
>
> (f) sequence will be influenced by the desirability of taking into account the science to come in the upper grades."

According to Dunfee and Grenlee,[1/] the criteria which determine the selection of science content in the elementary school program are based upon:

> ".....a new awareness of how children grow and learn and what demands are made upon them by society. And many notable educators seem to agree that the problem of health, safety, conservation, critical thinking, and problem solving are among the basic social concerns that call for scientific skills, attitudes and understandings."

According to Read,[2/] there is a relationship between the

1/M. Dunfee and J. Greenlee., Elementary School Science, Research, Theory, and Practice, Association for Supervision and Curriculum Development, National Education Association, Washington 6, D.C., 1952, pp. 18-19.

2/John G. Read, "Present Status and Problems of One Type of Grade Placement Research," Science Education, Vol. 42, No. 4, (October, 1958), pp. 349-357.

teaching of principles and the learning process. He says:

> "Learning has taken place when a pupil is able to use a principle to classify correctly phenomena of his own environment. Having learned, he can recognize that the observed phenomena are members of the same class as those from which he derived the principle in the teaching-learning process. He does not ever necessarily state the principle in words. In general, except for sampling errors in a test, he will classify correctly <u>every</u> common situation of his own environment which exemplifies this principle. The correct response will be made in the face of strong distractors seeking to divert him from his decision.
>
> There is a lowest grade level at which it is profitable, in terms of efficiency, to spend a reasonable amount of time in attempting to have pupils <u>understand</u> a physical science principle and learn to use it as a powerful tool for classifying phenomena of his current nearby environment. The level of efficiency was decided upon to be fifty per-cent; that is, it is more profitable to teach a principle at that lowest grade level where one-half or more of the experimental group could learn or understand a principle as evidenced by their ability to use effectively in a test situation. Note that there is no denial of the fact that many, <u>but not all</u>, principles can have partially been understood and partially used by pupils long before they reach the grade level suggested as a result of this research.
>
> All of these occurences are concerned with maturation. One aspect of maturation is the opportunity which it affords for pupils to adventure more widely in their environment. In two years, for instance, pupils may have just a few more <u>noticed</u> experiences; the membership of these experiences in a class of experience is not recognized. They are latent. When formal teaching presents the demonstration-exposition, these experiences are seen to be part of a hitherto faint pattern. The latent experience is developed, as it were, by the strong, direct, and precise thought process as a single principle is taught."

Tannenbaum[1] lists seven major generalizations around which science content may be based:

> "1. There are many kinds of living things and they are interdependent.
>
> 2. There are many forms of energy which can be changed from one to another, but most of the energy which men use is derived from the sun.
>
> 3. The earth is a small part of a vast universe containing other planets, stars, and astral bodies.
>
> 4. The earth's story, its history and current conditions, can be read from its rocks, soils, and waters.
>
> 5. Living things are dependent upon the earth and its atmosphere and the sun for their food, their shelter, and their very lives.
>
> 6. Men have learned how to use natural forces, both chemical and physical, to make their work easier.
>
> 7. Men must use their knowledge of science to keep themselves healthy and to improve society."

These generalizations give rise to the end results striven for by men of science throughout the ages. They are broad in nature but are formed from the organized disciplines of biology, chemistry, physics, and astronomy.

The Child and the Program. Blough[2] speaks of the elementary science program in the following manner:

1/Tannenbaum and Stillman, op. cit., p. 30.

2/Glenn O. Blough, It's Time for Better Elementary School Science., National Science Teachers Association, Washington 6, D. C., 1959, p. 13.

"The good science program is designed to fit the learners for which it has been developed. It gives all pupils an opportunity to channel their creative abilities into situations where they will do only those things that are purposeful."

Careful focus is placed upon the child and how he learns in the development of an effective science curriculum. The Forty-Sixth Yearbook 1/ recognizing child growth, accented the following areas as necessary to science teaching:

"The child is an investigator; a child reacts to all aspects of his environment; a child's imaginative activities contribute to his growth; a child seeks to participate in planning and carrying out his activities; a child follows his individual pattern in developing concepts; the child learns through seeking to achieve his purposes."

In summarizing, Tannenbaum 2/ quite deftly stated views supported by notable educators:

"As with almost no other area of the curriculum, science materials offer the teacher opportunities to capitalize on the many developmental phenomena which have been discovered about children. Just note. The child is an explorer; science gives him the chance to explore. The child is a problem solver; a science program can and should be built around opportunities to solve problems. The child is a searcher after

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1/Science Education in America, Forty-Sixth Yearbook of the National Society for the Study of Education, Part I, University of Chicago Press, Chicago, Illinois, 1947, p. 37.

2/Harold E. Tannenbaum and Nathan Stillman, Science Education for Elementary School Teacher, Allyn and Bacon, Inc., Boston, Massachusetts, 1960, p. 25.

> himself and his world; science programs should demand that he make rational decisions about his world. The child is a social being; a science program provides opportunities for him to work with his peers in a give-and-take situation where he brings his ideas to the group and where he takes ideas from the group."

The Teacher and the Program. With the demands placed upon science instruction by the modern, technical society, a great amount of scrutiny has been placed upon the teacher and the role he must play in the total science program. Consideration must be given to the teacher of the self-contained classroom; and secondly to the supervisor of science instruction. The role of the classroom teacher according to Freeman[1/] is to be aware....."of the values toward which he would like the children to grow, beginning with their ideas regardless of the imperfections and inaccuracies of these ideas." Many science educators have felt that the teacher's attitude has done much to cause a conflict within the elementary science program. This is perhaps due in part to the training and inconsistencies within a teacher's own basic education. In regard to this, Dunfee and Greenlee[2/] state: "Teachers themselves seem to

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1/Freeman, Dowling, Lacy and Tippett, Helping Children Understand Science, John C. Winston Company, 1954, p. 288.

2/M. Dunfee and J. Greenlee, op. cit., p. 48.

recognize the inadequacy of their training. Whenever teachers are asked their reasons for not teaching science, lack of training almost always ranks high." Blough and Blackwood[1] have given the following suggestions which prove helpful to elementary teachers:

> "1. Approach the teaching of science with confidence.
> 2. Don't expect to know the answers to all of the science questions which children ask you.
> 3. After a unit or area of science study has been decided upon, read some of the basic science textbooks that are on the learning level of the pupils you teach.
> 4. Do some of the experiments and other activities that are suggested in these books so you'll have the feel of the material.
> 5. Do some of the "things to do" that the books suggest - trips to take, observations to make, experiments to do, collections to make.
> 6. Talk with a junior high-school teacher near your school and enlist his help.
> 7. Don't feel too handicapped because you lack materials.
> 8. Let pupils experiment.
> 9. Start your science by teaching a unit with which you feel most at home.
> 10. Make all use possible of the teacher's manuals that accompany your textbook in science.
> 11. Keep track of your science material, your notes on reading, your plans, etc., so you can use them at a future time and so that other teachers may borrow them.
> 12. Talk to other grade teachers about what things they have found successful and be ready to share your experiences with them."

1/Glenn O. Blough and P. A. Blackwood, Teaching Elementary Science, Washington D. C., Government Printing Office, 1948, pp. 11-12.

Craig[1] discusses the relationship between the elementary science consultant and the classroom teacher:

> "In schools using consultants, the classroom teacher retains her full responsibilities for the instruction in the classroom, but she has the assistance of a consultant in certain fields, such as science, social studies arts. The consultant in science may assist the teacher through conferences, participation in classroom instruction, and the development of curriculum material and regional material in science.
>
> In conferences the consultant assists the teacher in planning. This planning should be mutual. The consultant is not a supervisor in the traditional sense. She participates with the classroom teacher in planning the science program rather than in submitting ready-made plans for the teacher to follow. The consultant can be of great assistance in the education of teachers in science while in service. She may build up enough interest on the part of the classroom teachers to create a demand for the conferences in science which she may conduct herself. Or, again, she may conduct excursions for classroom teachers to quarries, parks, and other places in the region.
>
> Consultants have been decisive factors in developing an integrated program of science through the elementary school and in coordinating secondary-school science with that of the elementary school."

The Fifty-Ninth Yearbook, Part 1,[2] reports the teaching-learning situation as fundamental and as important as the program of science itself. Nothing is wrong with good science

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1/Gerald S. Craig, Science for the Elementary School Teacher, Ginn and Company, Boston, Massachusetts, 1958, pp. 24-26.

2/Rethinking Science Education, Fifty-Ninth Yearbook of the National Society for the Study of Education, Part 1, University of Chicago Press, Chicago, Illinois, 1960, p. 138.

education that good science-teaching can not cure. The report continues: "The improvement begins with the assignment of a teacher who has a good science background, has a knowledge of the objectives for teaching science, is interested in teaching, knows how children learn, and wants to be a good teacher."

Navarra[1/] summarizes these ideas:

> "The good teacher is a guide; but he is more than that. Because of his experience and understanding he not only guides but also directs the learning into profitable channels. He keeps learning from being a narrow experience by broadening the interests of the learner and by opening up new avenues of learning."

Facilities and Materials. Even the best teacher is handicapped without proper facilities and materials. Educators agree quite readily that a science program does not need all of the tools to conduct a course in science instruction. Navarra,[2/] expressing his views on this topic, states:

> "The teacher must have adequate facilities and materials to carry on a successful science program. The necessary equipment is inexpensive and readily available, but the acquisition and use of such teaching aids must be carefully planned. Facilities and materials are means to an end. They are not ends in themselves."

1/Navarra and Zafforoni, *Science Today for the Elementary School Teacher*, Row-Peterson and Co., Elmsford, New York, 1960, p. 139.

2/*Ibid.*, p. 27.

Elementary science educators in general agree with the following criteria as established by Navarra[1/] in the over-all picture of facilities and materials in the successful elementary school program:

"(1)The Classroom
   a. furniture
   b. space
   c. bulletin boards
   d. water
   e. light and heat
   f. windows and out-of-doors
   g. a room that can be darkened
   h. a science table if possible
(2)Printed Materials
   a. textbooks
   b. trade books
   c. reference books
   d. free materials provided by industrial organizations and trade organizations.
(3)Materials for Experimentation
   a. materials obtained from the local community
   b. materials purchased from a scientific supply house
(4)Visual Aids
   a. motion pictures
   b. film strips
   c. radio, recordings and television

In concluding Navarra[2/] relates the idea of specific purpose in the selectionof these particular items: "Their chief purpose is to implant ideas in the minds of children and to help them understand scientific concepts."

1/*Ibid.*, pp. 27-52.

2/*Ibid.*, pp. 50-52.

Evaluation of the Program. In the words of the Fifty-Ninth Yearbook,[1/] "Evaluation should be considered an integral part of the total teaching-learning process, and it should be continuous." It further states:

> ".....evaluation is a continuing part of teaching and learning and is directed toward the appraisal of the quality of the teaching-learning process.
>
> .....true evaluation of teaching occurs only when that evaluation is in terms of the accepted goals of teaching in a particular institution.
>
> .....it is not enough to evaluate in terms of only one goal, such as the retention of facts. Evaluation should be in terms of all of the goals that are set for the teaching process."

In concluding, a recapitulation is made of the ever important necessities for the evaluation as supplying:

> ".....the impetus for the redirection of the teaching-learning process with all that this implies. The evaluation process will lead to the examination of previously accepted goals, of methods being used by teacher and learner in moving toward these goals, and of the merits of the very evaluation procedures themselves."

Pearl A. Nelson[2/] suggests the necessity for adequate evaluation:

1/Fifty-Ninth Yearbook, op. cit., p. 144.

2/John G. Read and Pearl Astrid Nelson, A View of Science Education Review and Forecast, Journal of Education, Volume 141, Number 2, December 1958, Boston University School of Education, p. 16.

> ".....if we keep constantly in mind the criteria of education in the elementary school and keep developing and improving techniques in the field. When we probe these educational criteria and find that we are accomplishing our goals, then we may turn our sights to bigger and better methods in teaching science and in evaluating the results."

3. Existing Research of Science Principles at the Elementary School Level

Research in the field of elementary school science is very limited. It appears that some thirty years ago science was taught almost exclusively at secondary and college level. It was within this period that some consideration was given to the elementary school child and his ability to conceive and interpret physical science principles. However, there appears even today to exist no general agreement in the elementary school as to what specific science principles should be taught.

Robertson[1] submitted an extensive list of science principles to persons actively engaged in teaching science in the elementary school grades, asking them to select those suitable for the elementary school. He finally secured a list of principles for elementary school science but concluded that opinions were of a wide range concerning their suitability.

1/Martin L. Robertson, "The Selection of Science Principles Suitable as Goals of Instruction in the Elementary School." Science Education 19: 1-4, February, 1935.

Leonelli[1] working at this same problem of selection and grade placement of principles tried to obtain an up-to-date rating of 81 principles developed by Robertson. He asked a jury of science experts and teachers to select those principles that should be included in elementary school science and to also suggest which grade level the principle should be introduced. Experts and teachers agreed well on selection. Of the 81 principles, seventy were chosen by 53 percent of the jurors. Concerning grade placement there was no such agreement. No one principle was selected by a majority for a particular grade. Indication was shown, however, that of the 81 principles, sixty-four could be absorbed through the span of the elementary science program.

In analyzing 163 courses of study, Dubins[2] likewise came to the conclusion that there is no general agreement as to what specific principles should be taught at the elementary school level. Less than 4 per-cent of the 476 major topics for study occur in more than one-half of the courses of study.

1/Renato E. Leonelli, The Selection and Grade Placement of Physical Science Principles in the Elementary School Curriculum, Unpublished Doctor's Dissertation, Boston University, 1952.

2/Mortimer I. Dubins, Current Practices in Elementary School Science with Reference to Courses of Study, Published from 1940 to 1952, and the Extent of Activities Undertaken for the Improvement of Instruction. Doctor's Dissertation, Boston: Boston University, 1953, p. 525.

Wheeler[1/] in collaboration with Lous and Mathes summarized recent trends in science education at the elementary school level:

> "Literature published during the past fifteen years was surveyed in light of: (1) subject-matter; (2) grade placement, and (3) general trends. Little uniformity was evidenced regarding selection of subject-matter for grade levels. A steady growth in curriculum development to include elementary science was found with objectives fairly well established. Science principles were introduced at all grade levels and showed increasing difficulty with grade advancement. There appeared to be no evidence as to argument on relationships of grade level and specific science experiences. The general trends were (1) that continuous K - 12 science programs are generally accepted; (2) that courses of study are organized with major science principles in mind."

Rather than determine specific science principle for particular grade levels, science educators favored a more general understanding of science at the elementary school level. Craig[2/] developed and published a sequential list of meanings which afforded the teacher some guidelines in planning science experiences for children.

1/Betty Lockwood Wheeler, "Review of Research in Elementary Science Education." School Science and Mathematics, Vol. LIX., (November, 1959), Number 8., pp. 626-27.

2/Gerald S. Craig, Science for the Elementary School Teacher, op. cit., p. 73.

To what extent may principles of science be taught at certain grade levels in the elementary school is answered by Jacqueline Buck Mallinson:[1]

> "One of the major problems of elementary science concerns the grade placement of certain areas of science and certain principles associated with them. Although a great number of studies have been undertaken with respect to this problem, the findings are still inconclusive.
>
> If certain criteria of understanding and achievement are postulated, then subject-matter areas and principles can apparently be assigned to certain grade levels at which they can be taught most effectively. However, if no particular criterion of achievement is pre-determined, then the findings of research tend to be most inconclusive.
>
> Apparently given levels of understanding and of achievement condition the grade placement of a science topic or principle far more than does the nature of the subject-matter area with which a topic or principle is concerned."

In summation of the existing research it would appear that elementary school science principles in general have been taught only incidentally and are less likely to be emphasized than in secondary school; but if specific efforts are made, and the material is modified to suit the learning-level of the student, practically any objective of science teaching can be attained at a given level.

1/Jacqueline Buck Mallinson, "Survey of Recent Research in Elementary School Science Education," School Science and Mathematics. Volume 58, pp. 605-609.

Summary of Current Related Research

Although many of the problems which confront science education in the elementary school have come from investigations in the field by well known science educators, there is evidence of a decided nature which may offer improvements in the modern elementary science program. Research has shown that little has been done relative to physical and biological principles, per se, at the elementary school level.

Even since the advent of Sputnik, and the research accomplished from the geophysical year study, little has been acknowledged relative to the teaching of physical science principles at the elementary school level.

It is advisable at this point to consider the conclusions drawn by Mallinson[1/] in her recent review of research. She states:

> "Elementary school science programs are far from established in many schools; the science training of elementary school teachers tends to be meager and relatively narrow and specialized, rather than generalized; elementary school science is taught with little or no equipment and with little or no time available for the teacher to prepare demonstrations; teachers agree to desirable aims and outcomes of the elementary school program and science should be an integral part of the total elementary school curriculum; supervisors and administrators believe that there is a definite trend toward more successful teaching of science."

1/<u>Ibid.</u>, p. 610.

Consideration should be given also to the conclusions drawn by Martin[1] in his research studies. Martin states:

> "A review of the research studies relating to the scientific principles which are suitable to serve as objectives of instruction in science reveals certain definite trends which are of importance for the organization and presentation of the materials and learning experiences of science instruction for the purposes of general education.
>
> In the literature devoted to the discussion of the curriculum in science there are numerous references to scientific principles, but it is difficult and in some cases impossible to find a definite, clearcut statement of the author's idea of what a principle is. Instructional materials, such as textbooks, prepared for use in science classes are often claimed to furnish training in the understanding of scientific principles, but they do not make clear the distinction between principles, facts, theories, postulates, hypotheses, and inferences."

The above conclusions are valuable, because they can be verified easily, and because they give an accurate image of just what progress can be made in the determination of a well-constructed elementary school science program. Research to this date seems to indicate the need for an all-inclusive, comprehensive work which will determine just which principles should be considered for the elementary science program. It is with this in mind that the present study is undertaken.

1/Edgar W. Martin, "Chronological Survey of Research Studies on Principles as Objectives of Instruction in Science," Science Education, Volume XXIX, February, 1945, pp. 45-52

CHAPTER III

REPORT OF STUDY AND ANALYSES OF DATA

Restatement of the Problem

The purpose of this study was to consider a number of physical science principles as developed by Harold E. Wise[1] for secondary education, and to judge their applicability to the elementary school curriculum as determined by elementary science supervisors, instructors and classroom teachers.

Techniques Employed

Techniques employed to determine the applicability of physical science principles in the elementary school science curriculum were the polled opinions of twenty science specialists throughout New England, who served as jurors for this study. These specialists were selected on the basis of their prominence in the elementary science field. Some criteria for this selection were textbooks written, periodical publications, membership on national committees and professional positions. Each of the specialists was requested to indicate on a score sheet, which contained a list of the two-hundred seventy-two physical science principles,

1/Harold E. Wise, A Determination of the Relative Importance of Principles of Physical Science for General Education, Unpublished Doctor's Dissertation, University of Michigan, 1941.

those principles suitable for the elementary science curriculum today assuming, of course, the simplest possible application of the principle.

A total of twenty responses was received from the original list of twenty-eight jurors. The following table represents the principles as selected by the jurors. (See Appendix for complete listing of principles).

Table I. Number of Original Principles of Physical Science as Selected by Twenty Science Specialists.

Jurors	Number of the Principle
Twenty jurors	97 - 103 - 162 - 269
Nineteen jurors	43 - 81 - 89 - 98 - 101 - 108 - 155 - 254 - 255 - 258 - 267 - 270 - 271
Eighteen jurors	25 - 65 - 67 - 157 - 252 - 260 - 265 - 266
Seventeen jurors	21 - 68 - 71 - 79 - 160 - 253 - 268
Sixteen jurors	47 - 154 - 161 - 183
Fifteen jurors	44 - 46 - 95 - 113 - 159 - 184 - 185 - 259
Fourteen jurors	10 - 64 - 70 - 73 - 90 - 137 139 - 272
Thirteen jurors	1 - 45 - 54 - 62 - 80 - 133 - 134 - 136 - 158 - 177 - 262
Twelve jurors	2 - 3 - 27 - 55 - 66 - 84 - 152 - 153 - 174 - 186
Eleven jurors	5 - 15 - 24 - 50 - 51 - 63 - 165 - 172 - 187 - 257
Ten jurors	8 - 59 - 78 - 86 - 164

Table I indicates that fifty percent of the combined jurors considered 88 of the 272 physical science principles as being suitable for inclusion in the elementary science curriculum.

More than fifty percent of the 272 physical science principles were regarded as having some reliability as to their acceptance in the elementary science curriculum.

Table 2. Numbers of Original Principles of Physical Science as Considered Unsuitable for Elementary Science Curriculum.

Jurors	Number of the Principle
No juror selected principles indicated.	58 - 76 - 77 - 83 - 127 - 128 - 129 - 131 - 148 - 168 171 - 178 - 179 - 200 - 201 202 - 206 - 212 - 213 - 214 223 - 224 - 231 - 232 - 233 234 - 237 - 242 - 243 - 245 246 - 250

Table 2 indicates that of the 272 physical science principles involved, 32 were considered not to be practicable for the elementary science curriculum.

Consideration was given by four of the jurors to the aspect of the consistency of the principle with the developmental level of the average student.

Location of the Median

The following figures have been based upon four categories; (1) the median of the original principles as acceptable to the elementary science curriculum by teachers as distinct from supervisors and professors in teacher education; (2) the median of the original principles as acceptable to the elementary science curriculum by science supervisors and specialists; (3) the median of the original principles as acceptable to the elementary science curriculum by professors in teacher education; (4) the median of the original principles as acceptable to the elementary science curriculum by the twenty jurors. The following tables resulted from the calculations.

Table 3. Location of the Median of the Original Principles by Teachers as Distinct from Supervisors and Professors in Teacher Education.

Limits	f.	Steps in the Process
160 - 164	1	High 162 72 ÷ 12 = 6.0
155 - 159	0	Low -91 72 ÷ 15 = 4.8
150 - 154	0	71 + 1 = 72 5 (class
145 - 149	0	interval)
140 - 144	0	
135 - 139	0	
130 - 134	1	$\frac{N}{2} = \frac{6}{2} = 3$
125 - 129	0	
120 - 124	2	
115 - 119	0	Approximate median = 119.5
110 - 114	0	
105 - 109	0	3 - 2 = 1
100 - 104	0	
95 - 99	0	$\frac{1}{2} \times 5 = \frac{5}{2} = 2.5$
90 - 94	2	
	N = 6	119.5 + 2.5 = 122.0 median

Table 3 shows that of the six jurors involved, a total high score was 162 principles as compared to a low of 91 principles.

In comparison with Table 1, the six jurors scored more than fifty percent (eighty-eight) of the original principles.

If percentage were to be given consideration as the final foundation for principles selected, the teacher as distinct from science supervisors and professors of teacher education would judge more than fifty percent of the 272 principles involved as suitable for elementary science teaching.

Table 4. Location of the Median of the Original Principles by Science Supervisors and Specialists.

Limits	f.	Steps in the Process
147 - 153	1	
140 - 146	0	High 147; 80 ÷ 12 = 6.7
133 - 139	0	Low -68; 80 ÷ 15 = 5.3
126 - 132	0	79 + 1 = 80; 6 (class interval)
119 - 125	1	
107 - 113	0	
100 - 106	1	$\frac{N}{2} = \frac{6}{2} = 3$
93 - 99	0	
86 - 92	2	
79 - 85	0	Approximate median = 92.5
72 - 78	0	
65 - 71	1	99.5 - 92.5 = 7.0
		7.0 ÷ 2 = 3.5; 92.5 + 3.5 = 96.0
N = 6		96.0 = median

Table 4. shows that of the six jurors involved, the total high score was 147 principles as compared to a low of 68 principles.

In comparison to Table 1. the six jurors scored more than fifty percent (eighty-eight) of the original principles.

The science supervisors and specialists selected fewer principles than teachers.

Table 5. Location of the Median of the Original Principles by Professors of Science Education.

Limits	f.	Steps in the Process
89 - 92	3	High 91; Low -43; 48 + 1 = 49; 49 ÷ 12 = 4.1; 49 ÷ 15 = 3.3; 4 (class interval)
85 - 86	2	
81 - 84	1	
77 - 80	0	
73 - 76	0	
69 - 72	0	$\frac{N}{2} = \frac{8}{2} = 4$
65 - 68	0	
61 - 64	0	Approximate median = 84.5
57 - 60	0	
53 - 56	1	
49 - 52	0	4 - 3 = 1
45 - 48	0	
41 - 44	1	$\frac{1}{2} \times 4 = 2.0$
	N = 8	84.5 + 2.0 = 86.5 median

Table 5. indicates that of the eight jurors involved, a total high score was 91 principles as compared to a low of 43 principles.

In comparison to Tables 3 & 4 the Professors of Science Education scored a lower median. Also noticeable was the range of high and low scored by each particular group.

As compared to Table 1. the Professors of Science Education appeared to be in more general agreement with the principles selected for further investigation.

Table 6. Location of the Median of the Original Principles by Twenty Jurors.

Limits	f.	Steps in the Process
160 - 169	1	
150 - 159	0	High 162 120 ÷ 12 = 10.0
140 - 149	1	Low -43 120 ÷ 15 = 8.0
130 - 139	1	119 + 1 = 120 10 (class
120 - 129	3	interval)
110 - 119	0	$\frac{N}{2} = \frac{20}{2} = 10$
100 - 109	1	
90 - 99	5	
80 - 89	5	Approximate median = 89.5
70 - 79	0	
60 - 69	1	10 - 8 = 2
50 - 59	1	
40 - 49	1	$\frac{2}{5} \times 10 = 4$
N = 20		89.5 + 4.0 = 93.5

Table 6. indicates that the combined twenty jurors present a median of 93.5, which represents approximately the fifty percent (eighty-eight) of the principles selected in Table 1.

Evidence is indicated by the previous Tables that principles which were primarily designated for secondary science education could be applicable to the elementary science program. This has been designated quite clearly, not only by Professors of Education, science supervisors and specialists but also by classroom teachers.

The validity of opinions expressed by classroom teachers must be given consideration.

In accordance with the previous figures, a score sheet with the eighty-eight physical science principles as determined by the jurors was prepared. A refinement of these principles was then to be determined by classroom teachers (K - 6) throughout the New England area. These principles were chosen on the basis of their applicability to the elementary science curriculum assuming the simplest possible application of the principle. Of the four-hundred eighty-three responses requested, a total of three-hundred twenty answered. The following table summarizes the percentage of selection of the eighty-eight principles.

Table 7. Principles Selected as Suitable for Inclusion in the Elementary Science Curriculum

Principle[a]	Professors in teacher education	Science Specialists Supervisors	Classroom Teacher
1. Energy can never be created or destroyed; it can be changed from one form to another with exact equivalence.	63	55	74
2. The work obtained from a simple machine is always equal to the work put into it less the work expended in overcoming friction...... .	63	50	59

[a] Principles are here numbered as in the original list

Table 7. (continued)

Principle	Professors in teacher education	Science Specialists Supervisors	Classroom teacher
3. When there is a gain in mechanical advantage by using a simple machine, there is a loss in speed and vice-versa...........	50	50	55
5. In the lever, the force times its distance from the fulcrum equals the weight times its distance from the fulcrum.........	75	55	45
8. When the resultant of all the forces acting on a body is zero, the body will stay at rest if at rest, or it will keep in uniform motion in a straight line if it is in motion.................	25	50	45
10. When one body exerts a force on a second body, the second body exerts an equal and opposite force on the first...	63	70	65
15. Bodies in rotation tend to fly out in a straight line which is tangent to the arc of rotation...............	75	55	50
21. Movements of all bodies in the solar system are due to gravitational attraction and inertia....................	63	85	77
24. Sliding friction is dependent upon the nature and condition of the rubbing surfaces, proportional to the force pressing the surface together, and independent of the area of contact.....................	75	55	41

(continued on next page)

Table 7. (continued)

Principle	Professors in teacher education	Science Specialists Supervisors	Classroom teacher
25. A body immerged or floating in a fluid is buoyed up by a force equal to the weight of the fluid displaced....................	88	90	72
27. The pressure at a point in any fluid is the same in all directions.............	38	60	43
43. A gas always tends to expand throughout the whole space available..................	88	95	78
44. The atmospheric pressure decreases as the altitude increases....................	50	75	71
45. The atmospheric pressure decreases with increasing water vapor content, other things being equal..................	25	65	48
46. A fluid has the tendency to move from a region of higher pressure to one of lower pressure; the greater the difference the faster the movement.....................	38	75	65
47. In the northern hemisphere great volume of air revolve in a counter-clockwise direction, and in the southern hemisphere they revolve in a clockwise direction.........	50	80	56
50. Gases may be converted into liquids by reducing the speed of their molecules...........	38	55	51

(continued on next page)

Table 7. (continued)

Principle	Professors in teacher education	Science Specialists Supervisors	Classroom teachers
51. The average speed of molecules increases with the temperature and the pressure................	63	55	51
54. Heat is liberated when a gas is compressed, and is absorbed when a gas expands....................	38	65	49
55. Most bodies expand on heating and contract on cooling; the amount of change depending upon the change in temperature...........	75	60	86
59. Heat is conducted by the transfer of kinetic energy from molecule to molecule	63	50	34
62. The more nearly vertical the rays of radiant energy, the greater the number that will fall on a given horizontal area, and the greater is the amount of energy that will be received by that area........	38	65	52
63. Since the earth rotates from west to east, the exact time (Arlington time) at which the sun is nearest overhead grows continually later as one travels westward around the earth's surface.............	38	55	71
64. The lower the temperature of a body, the less the amount of energy it radiates; the greater is the amount of energy radiated............	63	70	67

(continued on next page)

Table 7. (continued)

Principle	Professors in teacher education	Science Specialists Supervisors	Classroom teachers
65. Dark, rough, or unpolished surfaces absorb or radiate energy more effectively than light, smooth, or polished surfaces......................	88	90	80
66. Heat is transferred by convection, in currents of gases or liquids, the rate of transfer decreasing with an increase of the viscosity of the circulating fluid....	63	60	37
67. Bodies of land heat up and cool off more rapidly than bodies of water............	88	90	82
68. The atmosphere of the earth tends to prevent the heat of the earth from escaping, and the earth begins to cool only when the amount of heat lost during the night exceeds that gained during the day...	75	85	68
70. Condensation will occur when a vapor is at its saturation point if centers of condensation are available and if heat is withdrawn..........	38	70	60
71. Every pure liquid has its own specific boiling and freezing poing......................	75	85	72
73. The presence of a dissolved substance will cause the resulting solution to boil at a higher temperature and to freeze at a lower temperature than pure water.............	25	70	54

(continued on next page)

Table 7. (continued)

Principle	Professors in teacher education	Science Specialists Supervisors	Classroom teachers
78. The rate of evaporation of a liquid varies with temperature, area of exposed surface and saturation and circulation of gas in contact with the liquid...........	25	50	63
79. The principal cause of wind and weather changes is the unequal heating of different portions of the earth's surface by the sun; thus all winds are convection currents caused by unequal heating of different portions of the earth's atmosphere, and they blow from places of high atmospheric pressures to places of low atmospheric pressure.	63	85	74
80. The higher the temperature of the air, the greater the amount of moisture required to saturate it.............	38	65	67
81. Sound is produced by vibrating matter and is transmitted by matter....................	100	95	88
84. The speed of sound increases with an increase in temperature of the medium conducting it.........................	75	60	42
86. Sound waves are reflected in a direction such that the angle of incidence is equal to the angle of reflection..........	63	50	35
89. The higher the pitch of a note, the more rapid the vibrations of the producing body..........	89	95	76

(continued on next page)

Table 7. (continued)

Principle	Professors in teacher education	Science Specialists Supervisors	Classroom Teachers
90. When a sounding body is moving toward or away from an observer the apparent pitch will be higher or lower, respectively, than the true pitch of the sound emitted..............	63	70	55
95. Musical tones are produced when a vibrating body sends out regular vibrations to the ear while only noises are produced when the vibrating body sends out irregular vibrations to the ear........................	63	75	63
97. A magnet always has two poles and is surrounded by a field of force...........	100	100	90
98. Like magnetic poles always repel each other, and unlike magnetic poles always attract each other.................	100	95	90
101. Pieces of iron, steel, cobalt, or nickel may become magnetized by induction when placed within a magnetic field......	100	95	86
103. Like electrical charges repel and unlike electrical charges attract....................	100	100	79
108. An electric current may be produced in three ways: by rubbing or friction, chemical action, and the use of magnets.	100	95	85
113. All materials offer some resistance to the flow of electric current, and that part of the electrical energy used in overcoming this resistance is transformed into heat energy..	63	75	45

(continued on next page)

Table 7. (continued)

Principle	Professors in teacher education	Science Specialists Supervisors	Classroom teachers
133. Matter may be transformed into energy and energy into matter...............	38	65	57
134. Elements may be changed into other elements.......	63	65	59
136. All matter is made up of protons, neutrons, and electrons.................	75	65	64
137. Protrons and neutrons are found in the nucleus of an atom.....................	88	70	58
139. The mass of an atom is concentrated almost entirely in the nucleus.............	100	70	42
152. Energy is often transmitted in the form of waves.......	63	60	54
153. Waves travel in straight lines while passing through a homogeneous or uniform medium....	63	60	39
154. When waves strike an object they may either be absorbed, transmitted or reflected....	88	80	65
155. Light travels in straight lines in a medium of uniform optical density............	88	95	54
157. If a beam of light falls on an irregular surface, the rays of light are scattered in all directions...............	88	90	70
158. When light is reflected, the angle of incidence is equal to the angle of reflection......	50	65	36

(continued on next page)

Table 7. (continued)

Principle	Professors in teacher education	Science Specialists Supervisors	Classroom teachers
159. When light rays are absorbed, some of the light energy is transformed into heat energy..............	63	75	60
160. Whenever an opaque object intercepts radiant energy traveling in a particular direction, a shadow is cast behind the object.........	88	85	59
161. The color of objects depend upon what light rays they transmit, absorb, or reflect.....................	88	80	69
162. The darker the color of a surface the better it absorbs light................	100	100	87
164. When light rays pass obliquely from a rare to a more dense medium, they are bent or refracted toward the normal, and when they pass obliquely from a dense to a rarer medium they are bent away from the normal........	13	50	26
165. The dispersion of white light into a spectrum by a prism is caused by unequal refraction of the different wave lengths of light....................	25	55	43
172. Parallel light rays may be converged or focused by convex lenses or concave mirrors, diverged by concave lenses or convex mirrors..............	38	55	40
174. All rays passing through the center of a mirror are reflected upon themselves......	25	60	45

(continued on next page)

Table 7. (continued)

Principle	Professors in teacher education	Science Specialists Supervisors	Classroom Teachers
177. An image appears to be as far back of a plane mirror as the object is in front of the mirror, and is reversed....................	50	65	55
183. All matter is composed of single elements or combinations of several elements and can be analyzed by chemical processes and divided into these constituents.	38	80	52
184. All substances are made up of small particles called molecules, which are alike in the same substance (except for variations in molecular weight due to isotopes) but different in different substances...................	63	75	46
185. Elements are made up of small particles of matter called atoms, which are alike in the same elements (except for occasional differences in atomic weight, i. e. isotopes) but different in different elements.....................	63	75	42
186. Atoms of all elements are made up of protrons, neutrons, and electrons; and the difference between atoms of different elements are due to the number of protrons and neutrons in the nucleus and to the configuration of electrons surrounding the nucleus......	63	60	40

(continued on next page)

Table 7. (continued)

Principle	Professors in teacher education	Science Specialists Supervisors	Classroom Teachers
187. The electrons within an atom form shells about the nucleus, each of which contains a definite number of electrons.............	38	55	34
252. The natural movements of air, water, and solids on the earth are due chiefly to gravity plus rotation of the earth............	75	90	81
253. Strata of rocks occur in the earth's crust in the order in which they were deposited, except in the case of overthrust faults.	75	85	74
254. The earth's surface may be elevated or lowered by interior forces..........	88	95	81
255. When elevations or depressions are created on the earth's surface, the elevations are usually attacked by the agents of erosion, and the materials are carried to the depressions........	100	95	79
257. The rate of erosion is inversely proportional to the resistances of the rocks to decomposition and disintegration..................	38	55	46
258. Streams, generally, are lowering the surface land in some places and building it up in other places.........	100	95	88
259. Streams, potentially, have a regular cycle, youth, maturity, and old age...........	63	75	65

(continued on the next page)

Table 7. (continued)

Principle	Professors in teacher education	Science Specialists Supervisors	Classroom teachers
260. Falls or rapids tend to develop in a stream bed wherever the stream flows over a hard stratum to a soft one................	88	90	74
262. Glacial conditions are as a rule approached by increasing latitudes or altitudes.	38	65	50
265. Forces within the earth may cause breaks to appear in the earth's crust...........	63	90	87
266. Earthquakes are produced by the sudden slipping of earth materials along faults.....	75	90	85
267. Rocks may be molded to form mountains..................	88	95	81
268. Igneous rock may be formed from materials intruded into other rocks.................	75	85	68
269. Rocks may be formed by cooling and solidifying of molten materials..................	100	100	83
270. Rocks may be formed by the compacting and cementing of sediments.................	88	95	83
271. Rocks may be metamorphosed, changed by heat, pressure, and flexion...............	88	95	73
272. Parent material for the development of soils is formed through the physical disintegration and chemical decomposition of rock particles and organic matter...	63	70	66

Table 7. indicates that of the eighty-eight principles involved, professors in teacher education selected fifty percent or more than 77 of the principles.

Science specialists and supervisors selected fifty percent or more than eighty-eight of the physical science principles.

Fifty percent of the principles or more were selected by classroom teachers.

CHAPTER IV

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

1. Restatement of the Problem

The purpose of this investigation was to consider a number of physical science principles as developed for secondary education, and to judge their applicability to the elementary school curriculum as determined by elementary science specialists, instructors and classroom teachers.

2. Summary of Techniques Employed

The list of principles chosen as the basis of this study was that compiled by Harold E. Wise[1] for general education. This list was then sent to jurors who are engaged as science consultants, writers of science periodicals and textbooks, and Professors of Science Education. These jurors were requested to select those physical science principles which they believed should be included in the elementary school science curriculum assuming the simplest possible application of the principle.

From this list a second score sheet was constructed with those principles selected by the jurors to be sent to

1/Harold E. Wise, A Determination of the Relative Importance of Principles of Physical Science for General Education, Unpublished Doctor's Dissertation, University of Michigan, 1941.

classroom teachers. The elementary (K - 6) teachers were instructed to elect those principles which they believed should be included in the elementary science curriculum assuming the simplest, possible application of the principle.

3. Conclusions

Of the eighty-eight principles which were checked from the original list, seventy-eight of the physical science were found to be acceptable by six science supervisors and specialists, three hundred twenty classroom teachers, and eight Professors of Science Education for inclusion in the elementary school science curriculum. However, when each group was considered independently, it is noted that the majority of science supervisors and specialists included the entire eighty-eight principles; the classroom teachers included seventy-five of the principles; and the Professors of Science Education considered seventy-seven of the principles.

The three groups of educators, the science specialists and supervisors; the classroom teachers, and the Professors of Science Education, agreed better than eighty per-cent on twenty physical science principles. According to the findings, the following list of science principles should be given consideration for inclusion in an elementary school science curriculum:

Principle # 43

A gas always tends to expand throughout the whole space available.

Principle #65

Dark, rough, or unpolished surfaces absorb or radiate energy more effectively than light, smooth, or polished surfaces.

Principle #67

Bodies of land heat up and cool off more rapidly than bodies of water.

Principle #81

Sound is produced by vibrating matter and is transmitted by matter.

Principle #89

The higher the pitch of a note the more rapid the vibrations of the producing body.

Principle #97

A magnet always has two poles and is surrounded by a field of force.

Principle #98

Like magnetic poles always repel each other, and unlike magnetic poles always attract each other.

Principle #101

Pieces of iron, steel, cobalt, or nickel may become magnetized by induction when placed within a magnetic field.

Principle #103

Like electrical charges repel and unlike electrical charges attract.

Principle #108

An electric current may be produced in three ways; by rubbing or friction, chemical action, and the use of magnets.

Principle #162

The darker the color of a surface the better it absorbs light.

Principle #252

The natural movements of air, water, and solids on the earth are due chiefly to gravity plus rotation of the earth.

Principle #254

The earth's surface may be elevated or lowered by interior forces.

Principle #255

When elevations or depressions are created on the earth's surface, the elevations are usually attacked by the agents of erosion, and the materials are carried to the depressions.

Principle #258

Streams, generally, are lowering the surface land in some places and building it up in other places.

Principle #265

Forces within the earth may cause breaks to appear in the earth's crust.

Principle #266

Earthquakes are produced by the sudden slipping of earth materials along faults.

Principle #267

Rocks may be molded to form mountains.

Principle #269

Rocks may be formed by cooling and solidifying of molten materials.

Principle #270

Rocks may be formed by the compacting and cementing of sediments.

Nine principles might be questioned when considered for inclusion in the elementary school science curriculum because they were scored by less than fifty percent of two groups. If the assumption for inclusion is the majority of opinions, then the following should be eliminated from the curriculum:

Principle #8

When the resultant of all the forces acting on a body is zero, the body will stay at rest if at rest, or it will keep in uniform motion in a straight line if it is in motion.

Principle #27

The pressure at a point in any fluid is the same in all directions.

Principle #54

Heat is liberated when a gas is compressed, and is absorbed when a gas expands.

Principle #164

When light rays pass obliquely from a rare to a more dense medium, they are bent or refracted toward the normal, and when they pass obliquely from a dense to a rarer medium they are bent away from the normal.

Principle #165

The dispersion of white light into a spectrum by a prism is caused by unequal refraction of the different wave lengths of light.

Principle #172

Parallel light rays may be converged or focused by convex lenses or concave mirrors, diverged by concave lenses or convex mirrors.

Principle #174

All rays passing through the center of a mirror are reflected upon themselves.

Principle #187

The electrons within an atom form shells about the nucleus, each of which contains a definite number of electrons.

Principle #257

The rate of erosion is inversely proportional to the resistances of the rocks to decomposition and disintegration.

It is interesting to note that physical science principles as suggested by Wise[1/] some twenty years ago for secondary education should now be considered as suitable for the elementary science curriculum. Of the eighty-eight principles involved, two of the three groups, classroom teachers and Professors of Science Education, agreed quite readily to seventy-eight of the physical science principles. It is evident from the previous tables that more research needs to be done

1/Ibid., p. 1

at the elementary school level in regard to physical science principles.

3. Recommendations for Further Research

1. Expert opinion and the opinion of elementary classroom teachers served as a basis for this study. As a further study, an experimental method for each principle could be conducted to determine its success in certain areas of the elementary science curriculum.

2. A similar investigation might also be conducted concerning biological principles. The need for a study in this area is equally as necessary as in the physical sciences.

3. A similar study might be conducted over a three year period to determine the rapid advancement of science knowledge and increased interest of elementary school children today.

4. An investigation might be undertaken to determine the advantages of a structured over a non-structured curriculum in elementary science, including the principles used in this study.

5. An analysis of elementary science textbooks in use today might prove worthwhile in determining whether or not the principles which teachers believe should be included in the curriculum are included in the textbooks.

6. An investigation might be conducted to examine physical science principles recently formulated by the rapid change in this modern age of scientific development.

APPENDIX

COPY OF

LETTER SENT TO SCIENCE SPECIALISTS

Dr. ________ ________

Dear Dr. _______ _______,

At the present time under the guidance of Dr. Pearl A. Nelson, Assistant Professor of Elementary Science Education, Boston University, I am making a study of the physical science principles for general education and their applicability to the elementary school curriculum.

My plan is to correspond with elementary-science specialists to examine and rate these principles. You have been selected as one of these specialists, due to the outstanding work that you have done in this field.

A copy of two-hundred seventy-two principles is being sent with the request that you check those principles which could be applied to the elementary school science curriculum.

Realizing the tremendous work-load you now have, I would greatly be indebted to you for your assistance in this common venture. Upon the completion of the questionnaire please forward the materials to me in the enclosed envelope.

If ever I can be of service to you, please do not hesitate to write me.

Respectfully yours,

David R. Cawley

COPY OF

LETTER SENT TO TEACHERS

Dear Mr. ____________,

Under the direction of Dr. Pearl A. Nelson, Assistant Professor of Elementary Science Education, Boston University, I am making a study of the applicability of physical science principles for inclusion in the elementary science curriculum.

Because of the increasing emphasis in physical science study in the elementary school curriculum, - it is possible that many new principles need to be reviewed and old ones investigated.

You will help greatly by filling out the enclosed data sheet and checklist because you are in the best position to supply the information needed to complete the study.

Being a teacher myself, I realize the tremendous task with which you are now involved. May I ask for a few moments of your time and consideration.

Upon the completion of the questionnaire, at your convenience, please return the materials to me in the enclosed envelope before April 1, 1961.

If ever I can be of service to you, please do not hesitate to write me.

Gratefully yours,

David R. Cawley

COPY OF

CHECK-LIST OF PHYSICAL SCIENCE PRINCIPLES

Name of Scorer______________________________
Last First

Position______________________________

City and State______________________________

Number of years teaching experience____________

Particular grade in which you are now teaching__

Complete the following if applicable:

1. Approximate population of the community wherein school is located

Above 500,000___Between 250,000-500,000___Between 100,000-250,000___Between 50,000-100,000___Between 10,000-50,000___ Less than 10,000___

2. Principal occupational activities of the community:

Agriculture ___ Factories ___ Mills ___
Professional ___ Semi-Professional ___
Others (list) ______________________________

3. I desire a copy of the results of this study. Yes__No__

INSTRUCTIONS

On the following pages are listed a number of principles. Read the principle and then:

1. Place a __✓__ in the blank opposite the principle if you agree it should be included in the elementary science curriculum (K - 6) assuming the simplest possible application of the principle.

LIST OF 272 PHYSICAL SCIENCE PRINCIPLES[a/]

Principle #1: Energy can never be created or destroyed; it can be changed from one form to another with exact equivalence.

______

Principle #2: The work obtained from a simple machine is always equal to the work put into it less the work expended in overcoming friction.

______

Principle #3: When there is a gain in mechanical advantage by using a simple machine, there is a loss in speed and vice versa.

______

Principle #4: In the inclined plane, weight times height equals acting force times length, providing friction is neglected, and the force is parallel to the plane.

______

Principle #5: In the lever, the force times its distance from the fulcrum equals the weight times its distance from the fulcrum.

______

Principle #6: When forces act in the same direction, the resultant is their algebraic sum.

______

Principle #7: When two forces act upon the same object, the resultant is the diagonal of a parallelogram whose sides represent the direction and magnitude of the two forces. A single force represented by the diagonal may be resolved into two forces represented by the sides of a parallelogram.

______

Principle #8: When the resultant of all the forces acting on a body is zero, the body will stay at rest if at rest, or it will keep in uniform motion in a straight line if it is in motion.

______

---

a/Harold E. Wise, A Determination of the Relative Importance of Principles of Physical Science for General Education, Unpublished Doctor's Dissertation, University of Michigan, 1941.

Principle #9: The acceleration of a body is proportional to the resultant force acting on that body and is in the direction of that force.
______

Principle #10: When one body exerts a force on a second body, the second body exerts an equal and opposite force on the first.
______

Principle #11: The amount of momentum possessed by an object is proportional to its mass and its velocity.
______

Principle #12: The energy which a body possesses on account of its motion is called kinetic energy and is proportional to its mass and the square of its velocity.
______

Principle #13: The energy which a body possesses on account of its position or form is called potential energy and is measured by the work that was done in order to bring it into the specific condition.
______

Principle #14: A spinning body offers resistance to any force which changes the direction of the axis about which the body rotates.
______

Principle #15: Bodies in rotation tend to fly out in a straight line which is tangent to the arc of rotation.
______

Principle #16: Centrifugal force is directly proportional to the square of the velocity, to the mass, and inversely proportional to the radius of rotation.
______

Principle #17: The distance a body travels, starting from rest with a constant acceleration, is one-half the acceleration times the square of the time.
______

Principle #18: The speed gained by a body with constant acceleration is equal to the product of the acceleration and the time.
______

Principle #19: At any point on the earth's surface all bodies fall with a constant acceleration which is independent of the mass or size of the body if air resistance be neglected.
______

Principle #20: Any two bodies attract one another with a force which is directly proportional to the attracting masses and inversely proportional to the square of the distance between their centers of mass.

Principle #21: Movements of all bodies in the solar system are due to gravitational attraction and inertia.

Principle #22: The period of a pendulum swinging through short arcs is independent of the weight of the bob, but varies directly as the square root of the length, and inversely as the square root of the acceleration of gravity.

Principle #23: The distortion of an elastic body is proportional to the force applied provided the elastic limit is not exceeded.

Principle #24: Sliding friction is dependent upon the nature and condition of the rubbing surfaces, proportional to the force pressing the surfaces together, and independent of the area of contact.

Principle #25: A body immersed or floating in a fluid is buoyed up by a force equal to the weight of the fluid displaced.

Principle #26: The pressure in a fluid in the open is equal to the weight of the fluid above a unit area including the point at which the pressure is taken; it therefore varies as to the depth and average density of the fluid.

Principle #27: The pressure at a point in any fluid is the same in all directions.

Principle #28: Fluids have no elastic limit for compression.

Principle #29: Diffusible substances tend to scatter from the point of greatest concentration until all points are at equal concentration.

Principle #30: The rate of osmosis is directly proportional to the difference in concentration on opposite sides of the membrane.

Principle #31: Any homogeneous body of liquid free to take its own position, will seek a position in which all exposed surfaces will lie in the same horizontal plane. ______

Principle #32: When pressure is applied to any area of liquid in a closed container, it is transmitted in exactly the same intensity to every area of the container in contact with the liquid. ______

Principle #33: All liquids are compressible but only to a slight degree. ______

Principle #34: As the velocity of flow through a constriction increases, the pressure decreases. ______

Principle #35: The pressure of a saturated vapor is constant at a given temperature, and increases with an increase in temperature. ______

Principle #36: The free surface of a liquid contracts to the smallest possible area due to surface tension. ______

Principle #37: The volume of an ideal gas varies inversely with the pressure upon it, providing the temperature remains constant. ______

Principle #38: A liquid will rise in a capillary tube if the contact angle between the liquid and the side of the tube is less than 90° and will be depressed if the contact angle is greater than 90°. ______

Principle #39: The height to which a liquid rises in a capillary tube is directly proportional to the surface tension of the liquid and inversely proportional to the density of the liquid and to the radius of the tube. ______

Principle #40: If the same pressure is maintained, the volume of a gas is varied directly as the absolute temperature. ______

Principle #41: If the volume of a confined body of gas is kept constant, the pressure is proportional to the absolute temperature. ______

Principle #42: When a mixture of gases is confined, each exerts its own pressure without reference to the pressure exerted by the others.
______

Principle #43: A gas always tends to expand throughout the whole space available.
______

Principle #44: The atmospheric pressure decreases as the altitude increases.
______

Principle #45: The atmospheric pressure decreases with increasing water vapor content, other things being equal.
______

Principle #46: A fluid has the tendency to move from a region of higher pressure to one of lower pressure; the greater the difference the faster the movement.
______

Principle #47: In the northern hemisphere great volumes of air revolve in a counter-clockwise direction, and in the southern hemisphere they revolve in a clockwise direction.
______

Principle #48: In moving air, wind pressure increases as the square of the velocity.
______

Principle #49: The speed of diffusion of gases varies inversely with the square root of their densities.
______

Principle #50: Gases may be converted into liquids by reducing the speed of their molecules.
______

Principle #51: The average speed of molecules increases with the temperature and the pressure.
______

Principle #52: The amount of heat developed in doing work against friction is proportional to the amount of work thus expended.
______

Principle #53: The amount of heat which a constant mass of liquid or solid requires when its temperature rises a given amount is identical with the amount of change depending upon the change in temperature.
______

Principle #54: Heat is liberated when a gas is compressed, and is absorbed when a gas expands.

______

Principle #55: Most bodies expand on heating and contract on cooling; the amount of change depending upon the change in temperature.

______

Principle #56: A change in the state of a substance from gas to liquid, liquid to solid, or vice versa, is usually accomplished by a change in volume.

______

Principle #57: When a gas expands, heat energy is converted into mechanical energy.

______

Principle #58: The total change in length of a metal bar is equal to its co-efficient of linear expansion, times the original length, times the change of temperature in degrees centigrade.

______

Principle #59: Heat is conducted by the transfer of kinetic energy from molecule to molecule.

______

Principle #60: When two bodies of different temperatures are in contact there is a continuous transfer of heat energy, the rate of which is directly proportional to the difference of temperature.

______

Principle #61: Radiant energy travels in waves along straight lines, its intensity at any distance from a point source is inversely proportional to the square of the distance from the source.

______

Principle #62: The more nearly vertical the rays of radiant energy, the greater the number that will fall on a given horizontal area, and the greater is the amount of energy that will be received by that area.

______

Principle #63: Since the earth rotates from west to east, the exact time (Arlington time) at which the sun is nearest overhead grows continually later as one travels westward around the earth's surface.

______

Principle #64: The lower the temperature of a body, the less the amount of energy it radiates; the higher the temperature the greater is the amount of energy radiated.

______

Principle #65: Dark, rough, or unpolished surfaces absorb or radiate energy more effectively than light, smooth, or polished surfaces.

______

Principle #66: Heat is transfered by convection, in currents of gases or liquids, the rate of transfer decreasing with an increase of the viscosity of the circulating fluid.

______

Principle #67: Bodies of land heat up and cool off more rapidly than bodies of water.

______

Principle #68: The atmosphere of the earth tends to prevent the heat of the earth from escaping, and the earth begins to cool only when the amount of heat lost during the night exceeds that gained during the day.

______

Principle #69: Solids are liquefied and liquids are vaporized by heat; the amount of heat used in this process, for a given mass and a given substance, is specific and equals that given off in the reverse process.

______

Principle #70: Condensation will occur when a vapor is at its saturation point if centers of condensation are available and if heat is withdrawn.

______

Principle #71: Every pure liquid has its own specific boiling and freezing point.

______

Principle #72: If the vapor pressure of the water of hydration is greater than that of the moisture of the air, crystals will gradually yield up water to the air and vice versa.

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Principle #73: The presence of a dissolved substance will cause the resulting solution to boil at a higher temperature and to freeze at a lower temperature than pure water.

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Principle #74: Freezing point depression and boiling point elevation are proportional to the concentration of the solution.

Principle #75: The boiling point of any solution becomes lower as the pressure is decreased and higher as the pressure is increased.

Principle #76: Substances which expand upon solidifying have their melting points lowered by pressure; those which contract upon solidifying have their melting points raised by pressure.

Principle #77: The rate of vaporization decreases with an increase of concentration of the vapor in the gas in contact with the liquid, the temperature remaining constant.

Principle #78: The rate of evaporation of a liquid varies with temperature, area of exposed surface, saturation, and circulation of gas in contact with the liquid.

Principle #79: The principal cause of wind and weather changes is the unequal heating of different portions of the earth's surface by the sun; thus all winds are convection currents caused by unequal heating of different portions of the earth's atmosphere, and they blow from places of high atmospheric pressure to places of low atmospheric pressure.

Principle #80: The higher the temperature of the air, the greater the amount of moisture required to saturate it.

Principle #81: Sound is produced by vibrating matter and is transmitted by matter.

Principle #82: When energy is transmitted waves, the medium which transmits the wave motion does not move along with the wave, but the energy does.

Principle #83: The velocity of sound is directly proportional to the square root of the elasticity modulus and inversely proportional to the square root of the density of the transmitting medium.

Principle #84: The speed of sound increases with an increase in temperature of the medium conducting it.

Principle #85: The velocity of a wave is equal to the product of its frequency and wave length.

Principle #86: Sound waves are reflected in a direction such that the angle of incidence is equal to the angle of reflection.

Principle #87: The loudness of sound depends upon the energy of the sound waves and, if propagated in all directions, decreases inversely as the square of the distance from the source.

Principle #88: Smooth surfaced tubes may be employed to confine the direction of sound waves and thus prevent the rapid decrease in intensity with distance from source which would otherwise take place.

Principle #89: The higher the pitch of a note, the more rapid the vibrations of the producing body.

Principle #90: When a sounding body is moving toward or away from an observer the apparent pitch will be higher or lower, respectively, than the true pitch of the sound emitted.

Principle #91: The quality of a musical tone is determined by the pitch and intensity of the different simple tones or harmonics into which it may be resolved.

Principle #92: The frequency of the vibration of a stretched string is inversely proportional to its length, diameter, and the square root of its density; and directly proportional to the square root of the stretching force.

Principle #93: Two sound waves of the same or nearly the same frequency will destructively interfere with each other when the condensations of one coincide with the rarifactions of the other, provided that the directions of propagation are the same.

Principle #94: Sound waves or other energy impulses may set up vibrations in a body, the amplitude of which is increased if the impulses are exactly timed to correspond to any one of the periods of vibration of the body.

Principle #95: Musical tones are produced when a vibrating body sends out regular vibrations to the ear; while only noises are produced when the vibrating body sends out irregular vibrations to the ear.

Principle #96: Harmonious musical intervals correspond to very simple frequency ratios.

Principle #97: A magnet always has two poles and is surrounded by a field of force.

Principle #98: Like magnetic poles always repel each other, and unlike magnetic poles always attract each other.

Principle #99: The forces of attraction or repulsion between two magnetic poles varies directly as the pole strengths, and inversely as the square of the distance between the poles.

Principle #100: Magnets depend for their properties upon the arrangement of the metallic ions of which they are made up.

Principle #101: Pieces of iron, steel, cobalt, or nickel may become magnetized by induction when placed with in a magnetic field.

Principle #102: Electrostatic induction is the separation of charges on a conductor through the influence of a neighboring charge.

Principle #103: Like electrical charges repel and unlike electrical charges attract.

Principle #104: The force of attraction or repulsion between two small charged bodies varies directly as the product of the two charges, and inversely as the square of the distance between the charges.

Principle #105: In an uncharged body, there are as many protrons as electrons and the charges neutralize each other; while a deficiency of electrons produces a plus charge on a body, and an excess of electrons produces a negative charge.

Principle #106: Electrons have both a magnetic and an electric field.

Principle #107: Charges on a conductor tend to stay on the surface and to be the greatest on sharp edges and points.

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Principle #108: An electric current may be produced in three ways: by rubbing or friction, chemical action, and the use of magnets.

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Principle #109: An electric current will flow in the external circuit, when two metals of unlike chemical activity, are acted upon by a conducting solution, the more active metal being charged negatively.

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Principle #110: An electric current will be produced in a closed circuit including two strips of different metals if one of the junctions is heated or cooled.

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Principle #111: The electrical current flowing in a conductor is directly proportional to the potential difference and inversely proportional to the resistance.

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Principle #112: Electrons will always flow from one point to another along a conductor if this transfer releases energy.

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Principle #113: All materials offer some resistance to the flow of electric current, and that part of the electrical energy used in overcoming this resistance is transformed into heat energy.

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Principle #114: The resistance of a metallic conductor depends on the kind of materials from which the conductor is made, varies directly with the length, inversely with the cross-sectional area, and increases as the temperature increases.

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Principle #115: The amount of heat produced by an electric current is proportional to the resistance, the square of the current, and the time of flow.

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Principle #116: Electrical power is directly proportional to the product of the potential difference and the current.

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Principle #117: Energy in kilowatt hours is equal to the product of amperes, volts, and time (in hours) divided by one thousand.

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Principle #118: An electrical change in motion produces a magnetic field about the conductor, its direction being tangential to any circle drawn about the conductor in a plane perpendicular to it.

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Principle #119: An electro-motive force is induced in a circuit whenever there is a change in the number of lines of magnetic force passing through the circuit.

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Principle #120: An induced current always has such a direction that its magnetic field tends to oppose the motion by which the current is produced.

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Principle #121: The magnitude of an induced electro-motive force is proportional to the rate at which the number of lines of magnetic force change, and to the number of turns of wire in the coils.

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Principle #122: When a current carrying wire is placed in a magnetic field, there is a force acting on the wire tending to push it at right angles to the direction of the lines of force between the magnetic poles, providing the wire is not parallel to the field.

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Principle #123: In a parallel circuit the total current is the sum of the separate currents, the voltage loss is the same for each branch, and the total resistance is less than the resistance for any one branch.

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Principle #124: In a series circuit the total current is the same on all parts, the resistance of the whole is the sum of the resistance of the parts, and the voltage loss of the whole is the sum of the voltage losses of the parts.

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Principle #125: Condenser capacity varies directly with the area of the plates, and inversely as the insulation thickness between them.

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Principle #126: Alternating current charges a condenser twice during each cycle, inducing opposite charges on the two plates with the result that the current appears to flow through the condenser.

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Principle #127: By means of high frequency generators or vacuum tube oscillators, sustained or continuous oscillations can be produced in a condenser circuit. Their intensity is made to vary with audio-frequency currents in a transmitter circuit to produce radio waves.

Principle #128: Whenever a high-frequency oscillating current produces in the field around it oscillating electric and magnetic fields, energy in the form of an electro-magnetic wave is transmitted through space.

Principle #129: Electro-magnetic waves may produce electrical oscillation in a condenser circuit which is so adjusted as to oscillate naturally with the same frequency as that of the incominb waves.

Principle #130: Positively charged ions of metals may be deposited on the cathode as atoms when a direct current is sent through an electrolyte.

Principle #131: The mass of any substance set free by electrolysis is proportional to the current flowing and the time of flow; if the quantity of electricity is kept constant, the masses of the various substances set free are proportional to their electrochemical equivalents.

Principle #132: In a transformer the ratio between voltages is the same as that between the number of turns.

Principle #133: Matter may be transformed into energy and energy into matter.

Principle #134: Elements may be changed into other elements.

Principle #135: Atoms have great sub-atomic energy.

Principle #136: All matter is made up of protrons, neutrons, and electrons.

Principle #137: Protrons and neutrons are found in the nucleus of an atom.

Principle #138: Some elements have more than one atomic weight due to difference in the neutron content of their nuclei.

Principle #139: The mass of an atom is concentrated almost entirely in the nucleus.

Principle #140: The distance of successive electron shells from the nucleus of an atom and from each other are much greater than the dimensions of the nucleus itself.

Principle #141: The atoms of all radio-active elements are constantly disintegrating by giving off various rays (alpha, beta, and gamma) and forming helium and other elements.

Principle #142: Radio-active emission involves nuclear changes.

Principle #143: Atoms may be broken down by bombarding the nucleus with high speed particles such as protrons, alpha particles, or neutrons.

Principle #144: Radio-activity is independent of all physical conditions, heat, cold pressure, or chemical state.

Principle #145: Atoms or molecules may lose electrons when struck by high speed electrons or ions.

Principle #146: Gases conduct electric currents only when ionized.

Principle #147: When a stream of high speed electrons strikes a body, the atoms of that body emit X-rays.

Principle #148: In a tube which contains gas at low pressure subject to an intense electric field, cathode rays, streams of electrons, may move away from the negatively charged terminal at high speed.

Principle #149: A number of substances will emit electrons and become positively charged when illuminated by light.

Principle #150: Electrons are emitted from any sufficiently hot body.

Principle #151: Electrons change energy levels emitting or absorbing energy.

Principle #152: Energy is often transmitted in the forms of waves.

Principle #153: Waves travel in straight lines while passing through a homogeneous or uniform medium.

Principle #154: When waves strike an object they may either be absorbed, transmitted, or reflected.

Principle #155: Light travels in straight lines in a medium of uniform optical density.

Principle #156: The intensity of illumination decreases as the square of the distance from a point source.

Principle #157: If a beam of light falls on an irregular surface, the rays of light are scattered in all directions.

Principle #158: When light is reflected, the angle of incidence is equal to the angle of reflection.

Principle #159: When light rays are absorbed, some of the light energy is transformed into heat energy.

Principle #160: Whenever an opaque object intercepts radiant energy traveling in a particular direction, a shadow is cast behind the object.

Principle #161: The colors of objects depend upon what light rays they transmit, absorb, or reflect.

Principle #162: The darker the color of a surface the better it absorbs light.

Principle #163: The speed of light in any given substance bears a constant ratio to the speed of light in air.

Principle #164: When light rays pass obliquely from a rare to a more dense medium they are bent or refracted toward the normal, and when they pass obliquely from a dense to a rarer medium they are bent away fromthe normal.

Principle #165: The dispersion of white light into a spectrum by a prism is caused by unequal refraction of the different wave lengths of light.

Principle #166: Incandescent solids and liquids emit all wave lengths of light and give a continuous spectrum.

Principle #167: When white light passes through a substance which absorbs some waves and not others, certain bands of color are missing with the production of an absorption spectrum.

Principle #168: Two electro-magnetic waves having the same frequency and amplitude and traveling in nearly the same direction will interfere, constructively or destructively, depending on whether they are in or out of phase.

Principle #169: Luminous vapors and gases emit only certain kinds of light, producing bright line spectra.

Principle #170: When a body which emits a bright line spectrum is moving toward or away from the observer, the lines are shifted toward the short or long wave length ends of the spectrum respectively.

Principle #171: Each vibrating particle in the wave front of any wave motion may be considered as a secondary source of spherical wavelets which spread out from their sources with the velocity of the primary waves.

Principle #172: Parallel light rays may be converged or focused by convex lenses or concave mirrors, diverged by concave lenses or convex mirrors.

Principle #173: The curvature of a wave front will be changed a given amount by a lens, namely the reciprocal of the focal length.

Principle #174: All rays passing through the center of a mirror are reflected upon themselves.

Principle #175: When parallel light strikes a concave spherical mirror, the rays, after reflection, pass directly through the principal focus only if the area of the mirror is small compared to its radius of curvature.

Principle #176: In a plane mirror, a line running from any point on the object to the image of that point is perpendicular to the mirror.

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Principle #177: An image appears to be as far back of a plane mirror as the object is in front of the mirror, and is reversed.

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Principle #178: When light is incident upon a medium in which it will travel faster, and when the angle of incidence is greater than the critical angle, it is totally reflected.

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Principle #179: The sum of the reciprocals of the conjugate focal lengths of a lens or mirror equals the reciprocal of the principal focal length.

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Principle #180: The dimensions of an image produced by a lens or a mirror are the dimensions of the object as their respective distances from lens or mirror are to each other.

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Principle #181: A beam of light may become plane polarized as a result of any circumstance which results in the suppression of one of the rectilinear components of the vibration without affecting the component at right angles to it.

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Principle #182: Every pure sample of any substance, whether simple or compound, under the same conditions will show the same physical properties and the same chemical behavior.

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Principle #183: All matter is composed of single elements, or combinations of several elements, and can be analyzed by chemical processes and divided into these constituents.

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Principle #184: All substances are made up of small particles called molecules, which are alike in the same substance (except for variations in molecular weight due to isotopes) but different in different substances.

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Principle #185: Elements are made up of small particles of matter called atoms, which are alike in the same element (except for occasional differences in atomic weight, i.e. isotops) but different in different elements.

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Principle #186: Atoms of all elements are made up of protrons, neutrons, and electrons; and the differences between atoms of different elements are due to the number of protrons and neutrons in the nucleus and to the configuration of electrons surrounding the nucleus.

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Principle #187: The electrons within an atom form shells about the nucleus, each of which contains a definite number of electrons.

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Principle #188: Most atoms have the property of losing, gaining, or sharing a number of outer shell electrons.

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Principle #189: The energy shown by atoms by completing their outer shell by adding, losing, or sharing electrons determines their chemical activity.

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Principle #190: The valence of an atom is determined by the number of electrons it gains, loses, or shares in chemical reactions.

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Principle #191: A few elements are inert or chemically inactive because their atoms are so constructed as to be complete in themselves; i.e., their outer electron rings have no tendency to gain or lose electrons.

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Principle #192: The properties of the elements show periodic variations with their atomic number.

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Principle #193: Orderly arrangement of molecules, atoms, or ions in crystals give crystals regular form.

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Principle #194: A pure chemical substance may be prepared from raw materials through utilization of their physical and chemical properties.

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Principle #195: The materials forming one or more substances, without ceasing to exist, may be changed into one or more new and measurably different substances.

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Principle #196: The products of reacting substances may react with each other to form the original substances.

Principle #197: The total mass of a quantity of matter is not altered by any chemical changes occurring among the materials composing it.

Principle #198: No chemical change occurs without an accompanying energy change.

Principle #199: Each combustible substance has a kindling temperature which varies with its condition but may be greater or less than the kindling temperature of some other substance.

Principle #200: The heat of formation on any chemical compound equals its heat of decomposition.

Principle #201: When a chemical change takes place without the addition of heat from an external source, that substance which has the greatest heat of formation will tend to form.

Principle #202: Reactions occurring at ordinary temperatures are predominantly exothermic.

Principle #203: All chemical reactions which start with the same quantities of original substances, liberate the same amounts of energy in reaching a given final state, irrespective of the process by which the final state is reached.

Principle #204: If stress is applied to a reversible chemical system, there will be a readjustment in the system to relieve the stress.

Principle #205: In every sample of any compound substance formed, the proportion by weight of the constituent elements is always the same as long as the isotopic compositions of each element is constant.

Principle #206: When different amounts of one element are found in combination with a fixed weight of another element (in a series of compounds), the different weights of the first element are related to each other by ratios which may be expressed by small whole numbers.

Principle #207: The gravimetric composition of a compound may be found by multiplying the atomic weights of the elements by their subscripts in the formula of the compound.

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Principle #208: The speed of chemical reaction is increased by increasing the concentration of any of the reactants; and is decreased by decreasing the concentration of any of the reactants.

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Principle #209: Chemical reactions may be carried out more nearly to completion by any condition that establishes an unusually low concentration of one of the products.

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Principle #210: The rates of many reactions are affected by the presence of substances which do not enter into the completed chemical reaction.

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Principle #211: Equal volumes of all gases under the same conditions of temperature and pressure contain very nearly the same number of molecules.

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Principle #212: At a definite temperature and pressure, the relative combining volumes of gases and of gaseous products may be expressed approximately in small whole numbers.

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Principle #213: Equal amounts of heat raise equal numbers of atoms of all elements in the solid state through nearly equal intervals of temperature.

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Principle #214: The specific heats of many elements are approximately inversely proportional to their atomic weights.

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Principle #215: Every chemical element when heated to incandescence in a gaseous state has a characteristic glow and a characteristic spectrum which can be used to identify very small quantities of the element and which is related to, the molecular and atomic structure of the gas.

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Principle #216: Metals may be arranged in an activity series according to their tendency to pass into ionic form by losing electrons.

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Principle #217: Non-metals may be arranged in an activity series according to their tendency to pass into ionic form by gaining electrons.

Principle #218: Metals comprise a group of elements (other than hydrogen) whose atoms have a tendency to lose electrons readily and whose compounds, when dissolved in polar solvents, are capable of forming positive ions.

Principle #219: Non-metals comprise a group of elements whose atoms tend to gain electrons and whose compounds, when dissolved in polar solvents, are capable of forming **negative** ions.

Principle #220: Acids and bases are substances which in water solution ionize to give hydrogen and hydroxyl ions, respectively, from their constituent elements.

Principle #221: The activity of an acid or base is proportional to the degree of ionization of the compound when in solution.

Principle #222: The exchange of the negative and positive ions of acids and bases results in the formation of water and salt.

Principle #223: Electrolytes dissolved in water exist partially or completely as electrically charged particles called ions.

Principle #224: Simple ionic reactions are typically rapid reactions.

Principle #225: Salts of strong acids and strong bases under go negligible hydrolysis, while salts of inactive acids and inactive bases under go more marked hydrolysis.

Principle #226: Oxidation always involves the removal or sharing of electrons from the element oxidized, while the reduction always adds or shares with the element reduced.

Principle #227: Oxidations and reduction occur simultaneously and are quantitatively equal.

Principle #228: The solubility of solutes is affected by heat, pressure, and the nature of the solute and the solvent.

Principle #229: The ingredients of a solution are homogeneously distributed through each other.

Principle #230: Any substance soluble in two immiscible liquids will distribute itself between the two in proportion to its solubility in the two liquids.

Principle #231: The solubility of a gas in an inert solvent varies directly with the pressure to which a gas is subjected.

Principle #232: In a saturated solution, the product ofthe molar concentrations of the ions is constant.

Principle #233: Whenever the product ofthe concentration of any two ions in a mixture exceeds the value of the ion-product in a saturated solution of the compound formed by their union, this compound will be precipitated.

Principle #234: Whenever the product of the concentrations of any two ions in a mixture is less than the value of the ion-product in a saturated solution of the compound formed by their union, this compound, if present in the solid form, will dissolve.

Principle #235: Suspended particles of colloids have a continuous, erratic movement due to colloidal and molecular ion impacts.

Principle #236: Surface reactions predominate in all non-homogeneous reactions.

Principle #237: Colloids show greater chemical activity than the solid substances in mass, since the rates of reaction are proportional to the surface area of the solid, other factors being equal.

Principle #238: Colloids have the property of absorption to an unusual degree.

Principle #239: Colloidal particles may carry electrical charges.

Principle #240: Temperature changes, pressure changes, the presence of electrolytes, or the presence of oppositely charged particles may cause colloids to precipitate.

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Principle #241: Carbon atoms form a number of type groups of compounds which are determined by the elements present, and by the structural combinations of the atoms within the molecules.

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Principle #242: Unsaturated hydrocarbons are active chemically and form many compounds by addition.

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Principle #243: Saturated hydrocarbons are relatively inactive chemically, but form compounds by substitution.

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Principle #244: The boiling point of hydrocarbons increases with an increase in molecular weight.

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Principle #245: Molecules of some compounds undergo polymerization.

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Principle #246: Alcohols react with acids to form esters and ethers.

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Principle #247: Alcohols oxidize to aldehydes, ketones and acids.

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Principle #248: Elements and compounds to which the cells of living organisms react specifically produce physiological effects.

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Principle #249: Enzymes, vitamins, and hormones are chemical regulators of the reactions that occur in living organisms.

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Principle #250: The properties of alloys are dependent upon the relative amounts of their components, the extent of their compound formation, and upon the crystalline structure of the mixture.

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Principle #251: Each element has its own characteristic X-ray spectrum.

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Principle #252: The natural movements of air, water, and solids on the earth are due chiefly to gravity plus rotation of the earth.

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Principle #253: Strata of rocks occur in the earth's crust in the order which they were deposited, except in the case of overthrust faults.
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Principle #254; The earth's surface may be elevated or lowered by interior forces.
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Principle #255: When elevations or depressions are created on the earth's surface, the elevations are usually attacked by the agents of erosion, and the materials are carried to the depressions.
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Principle #256: Continual erosion results in decreasing the average density of continental masses, and continual deposition in increasing the average density of rocks under the ocean.
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Principle #257: The rate of erosion is inversely proportional to the resistances of the rocks to decomposition and disintegration.
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Principle #258: Streams, generally, are lowering the surface land in some places and building it up in other places.
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Principle #259: Streams, potentially, have a regular cycle; youth, maturity, and old age.
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Principle #260: Falls or rapids tend to develop in a stream bed wherever the stream flows over a hard stratum to a soft one.
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Principle #261: The transporting power of streams varies approximately as the fifth power of the velocity.
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Principle #262: Glacial conditions are as a rule, approached by increasing latitudes or altitudes.
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Principle #263: Glacial abrasions occur in proportion to the weight of the ice and the velocity of its movement.
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Principle #264: Under high pressures which occur in the earth's interior, materials that usually are solids have the capacity to flow slowly and thus bring about equalization of pressure differences on the surface.
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Principle #265: Forces within the earth may cause breaks to appear in the earth's crust.
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Principle #266: Earthquakes are produced by the sudden slipping of earth materials along faults.
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Principle #267: Rocks may be molded to form mountains.

Principle #268: Igneous rock may be formed from materials intruded into other rocks.
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Principle #269: Rocks may be formed by the cooling and solidifying of molten materials.
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Principle #270: Rocks may be formed by the compacting and cementing of sediments.
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Principle #271: Rocks may be metamorphosed, changed by heat, pressure, and flexion.
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Principle #272: Parent material for the development of soils is formed through the physical disintegration and chemical decomposition of rock particles and organic matter.
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