The principal objective of this thesis was to compare science education in the secondary schools of the United States with that of the Republic of China. The historic evolution of the science curriculum, objectives and methods of instruction of these two countries in each period are summarized in the following table:
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<tr>
<th>Period</th>
<th>Country</th>
<th>Country</th>
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</thead>
<tbody>
<tr>
<td>1635</td>
<td>Latin grammar school: to glorify God, no science or antiscience.</td>
<td>There was no science education in this period.</td>
</tr>
<tr>
<td>1750</td>
<td>The academy and public high school: practical and expository. Science-centered curriculum. The system of science itself was the content of education. The main pedagogic method was memory.</td>
<td>Ancient Chinese sages idea about essence of knowledge was similar to Piaget's conception: to know an object is to act on it, to know is to modify, to transform the object (物), and to understand the process of this transformance and as a consequence to understand the way the object is constructed. (14) (21, pp. 176-186)</td>
</tr>
<tr>
<td>1751</td>
<td>Standardization of the curriculum: college preparatory. Subject-centered curriculum. Materials suitable for pupil's development was chosen from natural science and used as educational content.</td>
<td>Imitated American 6-3-3 plan in 1930s. Subject-centered curriculum. The main method was to redo demonstrations and experiments of cookbook-like exercise. The predominant objective is college</td>
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<tr>
<td>1872</td>
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<td>1873</td>
<td></td>
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<tr>
<td>1900</td>
<td>The period of reorganization: changing from 8-4 plan, four years of high school training to 6-3-3 pattern. Birth of junior high school in the American school system. Evolution from college preparatory towards functional. The dawn of the</td>
<td></td>
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<tr>
<td>Period</td>
<td>Country</td>
<td>The United States</td>
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<tr>
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<tr>
<td>1955</td>
<td></td>
<td>atomic age intensified a belief in the discipline-centered curriculum.</td>
</tr>
<tr>
<td>1955</td>
<td></td>
<td>Revolution in science teaching: course content improved studies. Discipline-centered curriculum. Students were involved with &quot;discovery&quot; learning. Cognitive process and the structure of knowledge in science became important. The objective was to provide scientific personnel, to promote the advent of the space age, and for college preparation.</td>
</tr>
<tr>
<td>1965</td>
<td></td>
<td>Humanistic curriculum. Paid attention to individualized instruction and integrated science. Piaget's cognitive theory was widely discussed and applied in science education. The objective was to develop scientifically literate citizens.</td>
</tr>
<tr>
<td>1980</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period</td>
<td>Country</td>
<td>Country</td>
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<tr>
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</tr>
<tr>
<td></td>
<td>The United States</td>
<td>The Republic of China</td>
</tr>
<tr>
<td>1981</td>
<td>&quot;Cultivate the student's ability to make the best decision and control his own fate&quot; were added to the objectives of science education.</td>
<td>Prepare to prolong the compulsory education to twelve years. Accelerate the modernization of the country.</td>
</tr>
</tbody>
</table>
A Comparison Between Science Education in the Secondary Schools of the United States and the Republic of China

by

Tai-Fu Perkin Lu

A THESIS

submitted to

OREGON STATE UNIVERSITY

in partial fulfillment of the requirements for the degree of

Master of Science Education

Completed June 1981
Commencement June 1982
To My Wife

Charity Huant

As a Souvenir of Our Ivory Wedding
ACKNOWLEDGMENTS

The writer wishes to express his sincere appreciation to:

Dr. Thomas Parker Evans, my advisor, for his guidance in the preparation of this thesis, and assistance in my study at Oregon State University.

My mother, without her aid my studying abroad would have been impossible.

My wife, for her help and encouragement made this thesis possible.
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A COMPARISON BETWEEN SCIENCE EDUCATION IN
THE SECONDARY SCHOOLS OF THE UNITED
STATES AND THE REPUBLIC OF CHINA

I. INTRODUCTION

Science is an intellectual tool created by man as a result of his interaction with his environment (21, p. 95). Level of scientific advancement is viewed by people throughout the world as a means for a country to gain status and to secure its national defense. Doubtlessly, science education is the foundation for the development of scientists and science. As a result, countries all over the world are beginning to promote science education.

In 1950s and 60s, the development of science education in the Republic of China (R.O.C.), influenced by the leadership of the United States in UNESCO, was similar to that of the United States. But the background of politics, culture, and economy is different in both countries, and as a result, the development of science education has not been the same.

This thesis compares science education in the secondary school of the United States with that of the Republic of China. Such a study has the potential of increasing the understanding of science education in both countries and, therefore, intensifying mutual appreciation of Sino-American cultural interflow.
A. STATEMENT OF THE PROBLEM

This thesis proposes to make a comparative study of the history, objectives, and instructional methods of science education in the secondary schools of the United States and the Republic of China. The materials about science education in the United States were based largely upon John H. Woodburn and Ellsworth S. Obourn's *Teaching The Pursuit of Science* (30), Alfred T. Collette's *Science Teaching in the Secondary School, a Guide for Modernization Instruction* (5), and the author's impression of travelling across the continent; science education in the Republic of China was based upon the author's cultural background, and his experience of teaching in the Republic of China.

A historical evolution of science curriculum and objectives of science education in each period is discussed. An overview of instructional methods in science teaching and a comparison of current situations are also presented.

B. IMPORTANCE OF THE PROBLEM

Chinese proverb: "Never be afraid of being ignorant upon the goods; just compare them!" So comparison can frequently lead to greater understanding and appreciation of those things being compared. It provides opportunity to examine and gain new insights in science education from a different point of view and to provide ideas for adoption.

For instance, in the United States, science and technology have been successfully applied to many of man's problems; in fact, their
application has been so successful as to give rise to a blind faith in science and technology. (10 p. 82) But American science education today wants adolescents to know that science and technology have limitations; i.e., problems exist that can have no scientific or technological solution without an accompanying change in human values. (13, p. 1243) And the idea of freedom that has glorified American science, now has the tendency of being misused by young people. The idea in Table II of this thesis, a traditional idea developed by Chinese sages on the ground of humanism, will emphasize the teaching of young people the relationship between the investigation of objects (Steps 1 and 2) individual (Steps 3 to 5) and society (Steps 6 to 8). Teachers in the Republic of China suggest using steps 3 to 8 as being helpful in solving ethical and value-laden questions.

On the contrary, the educators of the Republic of China have made their efforts to imitate American science education. But science education is a reflection of that society, and the societal gap between the United States and the Republic of China still exists. So local conditions must be taken into consideration in order to have a better adoption.

C. LIMITATIONS OF THE STUDY

This study is subject to the following limitations:

1. The discussion concentrated mainly on the comparison of history, objectives, and instructional methods of science education. Other areas of education are omitted;
2. Emphasis is placed on science education related to chemistry and physics;

3. The historical evolution of science curriculum and objectives of science education in the United States discussed in Chapter II and Chapter III are substantially a kind of report, following the guidance of Thomas Parker Evans, (the author's advisor) and Alfred T. Collette's *Science Teaching in the Secondary School, a Guide For Modernization Instruction* (5), and John Woodburn and Ellsworth Obourn's *Teaching the Pursuit of Science*.

4. The historical evolution of science curriculum and objectives of science education in the Republic of China are largely based on the author's experiences.

**D. DEFINITION OF TERMS**

The following definitions apply to the terms as they were used in this study.

1. **Science-centered curriculum**: Science was presented as a body of information, and pupils were apt to think of science only in this light. Science textbooks were written from an inductive point of view; science teaching was primarily by lecture and recitation and contained a limited amount of teacher demonstration but practically no laboratory work.

2. **Subject-centered curriculum**: The subject-centered curriculum was an improved form of the science-centered curriculum. The instructional material suitable for pupil's development was chosen from the domain
of natural science. It was compiled according to difficulty—from simple to complex. This is called "systematic learning," and is the traditional curriculum which has been long supported by all countries over the world.

3. **Experience curriculum:** Child is the center of this curriculum, so it is also called "child-centered curriculum." The central thought of experience curriculum is "Learning by Doing," so students' activities include the problem solving method, life experience, and students' interest are the focus of education.

4. **Discipline-centered curriculum:** Most of the curriculum was compiled by professors and scientists. The courses of study are highly theory and concept-oriented, specialized and have a professional point of view. Bruner's *Learning by Discovery* is the basis of instructional methods for developing this curriculum.

5. **Humanistic curriculum:** This lays stress on the interrelationship of the sciences, the broader meanings of science and the humanistic, social, historical aspects that are so important to liberal education. It proposes that "the major goal of science education is to develop scientifically literate and personally concerned individuals with a high competence for rational thought and action (19)."
What science teaching is at any one period of history is determined by the points of view and pedagogical practices passed along through many generations of teachers.

Similarly, what science teaching is in any one part of the world is determined not only by the local interests, customs, and traditions, but also by beliefs and practices developed elsewhere and adopted or adapted to local conditions. (30, pp. 168-169)

Before 1955, the development of science education in the United States and the Republic of China may be classified as the self-developed period. There was little contact between the two countries, and, thus, little influence on one another. But as a result of advances in transportation and increases in communication with the United States, the Republic of China adopted Physical Science Study Committee Physics Course (PSSC), Chemical Education Materials Study (CHEMS), Biological Sciences Curriculum Study (BSCS) in 1964 as her instructional materials for science education in senior high schools. Later, in 1976, the Republic of China, using Intermediate Science Curriculum Study as references, developed Chinese physics and chemistry textbook materials for the junior high schools. As a result, the interflow of science education between the two countries was increased. Therefore, after 1955 the development of science education in the United States and the Republic of China may be classified as the mutual-influenced period.
PART I. Self-Developed Period

A. The History of Science Education of the United States

The Latin Grammar School (1635-1750)

No science or antiscience

The first secondary school in America was established in 1635. It was the Boston Public Latin Grammar School and was established for the expressed purpose of preparing students for Harvard University. Following the establishment of this school in Boston, many Latin grammar schools sprang up in the New England area. The people of this time felt that there was need for a ministry to help the people keep the faith. Harvard University was founded to prepare these ministers; however, Harvard was dependent upon the Latin grammar schools for its supply of students. (3, p. 54)

In the Latin grammar schools of colonial America, there is no evidence that science was a part of the curriculum. The "curriculum of these first secondary schools not only excluded science but was distinctly antiscientific from a philosophical point of view." (30, p. 170)

The Early High School (1750-1871)

Science-centered curriculum

The academy movement developed and flourished between 1750 and 1850. (30, p. 170) It grew out of a concern that the Latin grammar schools were not "practical" enough and did not offer a useful program for the non-college-bound student. Few of the Latin grammar schools were capable of changing to this practical curriculum, therefore, many of them died. Some few remained as excellent college preparatory schools.
Although most of the Latin grammar schools ceased to exist, their influence did not die as they clearly influenced the academies that eventually took their place. The curriculum of the early academies was torn between the popular demands of the people for a "practical" curriculum and the classical syllabus of the Latin grammar schools. Consequently many of the newly developed academies were different from the Latin grammar schools in name only. (9, p. 2)

The precise science curriculum of the academies would not be possible to identify because many academies passed out of existence without leaving a record. Also, there were no uniform or common curriculum. However, nature philosophy, a forerunner of physics, was a part of the curriculum of some academies. Geography, astronomy, chemistry, and botany were frequently taught in the academies.

Many of the American academies did not die as did the Latin grammar schools. They slowly evolved, during the last half of the nineteenth century into a new type of secondary school—the "high school." This evolution was brought about by many factors such as the following: (1) state funds were increasingly being made available to academies; (2) there were increased arguments made against academies, because they had become exclusive and aristocratic; (3) the population had increased immensely; (4) a strong cry was sounded for universal, free secondary education based on a broader curriculum and for standardization; (5) a demand was being made for a secondary education that would be better adapted to the needs of all classes; and (6) there was a greater need for an educated citizenry. The academies had changed greatly since their birth in the eighteenth century. (9, p. 7)
The free public high school grew out of the academy movement. The first of these was the English High School, which was established in Boston about 1821. The science curriculum of the early public high schools was influenced by the academies and the offerings consisted for the most part of natural philosophy, natural history (largely biological science), and chemistry.

**Standardization of the Curriculum (1872-1918)**

**Subject-centered curriculum**

In 1872, Harvard College announced that work in physics and other high school sciences would be accepted for college entrance. Shortly after, chemistry also was required for admission to college. Within a few years, most of the colleges had followed the lead of Harvard, and the offerings in high school showed increasing effects of college influence. Other factors that helped the standardization of the curriculum were as follows:

1. In 1870 Michigan established a system of accrediting the secondary schools so that the students might enter college without taking entrance examinations. This system spread to other states and resulted in inspection of the high schools by "high school visitors," usually college personnel. (9, p. 9)

2. "In 1864, the New York Board of Regents established preliminary examinations that provided standards both for graduation from high school and for admission to the colleges of the states of New York." (3, p. 68) This board established a system of "counts" in 1890. A "count" was the equivalent of ten weeks of work in which the student recited five times a week. The system of using time to
standardize a course of study soon was established as a means of standardizing the curriculum throughout the United States.\(^{(3)}\)

One "credit" of high school science is still typically one hour of class per day for five days a week. There is a slight trend away from the one hour per day, but the use of five classes per week is the usual practice in most present day American high schools.

3. In 1892, the National Education Association appointed a Committee of Ten, chaired by Charles Elliot, president of Harvard, to consider the conditions and offer recommendations concerning the secondary school.\(^{(17)}\) This committee organized conferences, of ten members each, to view the various subject-matter areas. The committees considered the conditions of the secondary school and offered their recommendations in a report which was published in 1893. Some of the recommendations for high school science are as follows: (1) classes should be taught the same way no matter what the student's probable destination; (2) the allotment of time and the method of instruction should be the same year by year—each science course in high school was recommended to include one entire year of study; (3) every subject should not be pursued by every child; (4) the laboratory should be an integral part of science teaching, and a minimum length for the laboratory ought to be one and a half hours in duration; (5) a laboratory was suggested for Saturday morning; (6) science should be articulated from grades one through twelve; (7) a notebook should accompany all laboratory work; (8) a prescribed sequence of science offerings was suggested; (9) the laboratory ought
to include the laboratory work as well as written and oral examinations; (10) one afternoon each week ought to be used for out-of-doors science instruction; and (11) laboratory teaching was to based on faculty psychology. (17, pp. 1-54)

4. A committee on college entrance requirements was appointed by the National Education Association at about the same time as the appointment of the Committee of Ten. The purpose of this new committee was to study and suggest recommendations pertaining to college entrance requirements. The committee published its report in 1899. This report contained the following suggested sequence for the high school: (1) first year—physical geography; (2) second year—biology; (3) third year—physics; and (4) fourth year—chemistry. (18, p. 651) In addition, the committee recommended that one year of science in the secondary school be required for admission to any college or university.

5. The College Entrance Board was established around 1900 for the purpose of developing standard examinations in each subject for colleges throughout the United States. (12, pp. 513-514)

During these times, courses of study were prepared by college teachers of science, and many of the textbooks were written by them. Physics became the most important science offering in the high school with chemistry as a close second. Biology courses, which were really combined one-year courses in botany, zoology, and physiology, were introduced. These courses had little or no integration. Geology was in the curriculum, but its popularity declined towards the beginning of the century.
The subject-centered curriculum was an improved form of the science-centered curriculum. The instructional materials suitable for pupil's developmental stage was chosen from the domain of natural science as its educational content. It was compiled according to difficulty—from simple to complex. This is called "systematic learning" and is the traditional curriculum which has been long supported by all countries over the world. (16, p. 8)

The Period of Reorganization (1918-1930)

Curriculum Expansion and Readjustment

Experience curriculum: A number of important changes occurred in the organization of the schools between 1918 and 1930 which greatly influenced the science program. It was during this period that the high school population markedly increased. There was a rapid growth of the 6-3-3 organizational pattern in the schools, and the junior high school movement was at its peak. General science was introduced in the curriculum at grade nine, while biology became a tenth-year subject. Physics and chemistry were taught at either grades eleven or twelve. World War I spawned increased emphasis on chemistry and its related technology. As a result, in part, chemistry became an even more respected part of the senior high school curriculum. (11, p. 2)

One of the first reported divorces from the point of view which dominated the high school during the college domination period was a bulletin published by the Commission on the Reorganization of Secondary Education in 1918. The Commission was formulated in 1913 by the National Education Association. In this bulletin, the Commission gave several reasons for the need for a reorganization of secondary education.
These reasons were as follows: (1) changes in society, (2) increase in secondary-school population, and (3) changes in educational theory. They recommended that the high school children, twelve to eighteen years of age, be divided into two sections, a junior and senior high school. (6, p. 18)

General science developed very rapidly in the 1920s and was even introduced in the seventh grade in some schools. The unitary aspect of general science influenced the development of many types of integrated courses. This influence caused a de-emphasis in the specialized courses such as physics and chemistry. Both biology and general science stressed the study of the environment and the functional aspects of science.

The tremendous influx of students into the high school created some problems and exacerbated others, but most important among the problems was the narrowness of purpose of the college-prescribed curriculum. As a result, Dr. John Dewey advocated his experience curriculum. A representative curriculum of this plan is the California Plan. The science courses of study of this curriculum was based on pupil's interest and life experience. Pupil's series studies adopted problem-solving methods. It is a kind of child-centered curriculum. (16, pp. 8-9)

Pre-World War II and World War II (1930-1945)

Woodburn and Obourn classify the period between 1930 and 1950 as the period of "modern influences" on the secondary schools science curriculum. (30, p. 173) It was during this period that the National Society for the Study of Education published its thirty-first yearbook,
A Program for Teaching Sciences. This publication has been instrumental in shaping the science curriculum of American schools into its modern form. (9, p. 21)

Between 1930 and 1945 the junior high school movement leveled off, and general science was introduced in the seventh and eighth grades. Advanced general science courses were proposed for grades eleven and twelve to replace physics and chemistry. Biology became a basic science offering. World War II gave new impetus to the study of physics, it also brought about a great emphasis on the practical aspects of science, and consequently courses such as aviation, photography, and electricity were introduced into the curriculum.

Post World War II (1945-1960)

By 1945 about 75 percent of boys and girls of high school age were attending secondary schools. More science courses were introduced to handle increasing enrollments. Courses such as earth science and physical science were offered; general science was an important offering of the science program. Biology became popular, but physics and chemistry showed a marked decline in enrollment. Science fairs and congresses became common during this period.

Science Education in American Schools was published by the National Society for the Study of Education in 1947. This publication emphasized a need to take a closer look at general science. They felt that problem solving was not receiving proper attention in science teaching and that there was too much repetition. The committee stressed the importance of science for functional values in aiding the adjustment of individuals. They urged support of the growing tendency to offer
physical science in the high school for those not going further in the study of science. (20, pp. 1-306)

At the halfway point of the twentieth century, there appeared a new agency in the United States that rapidly added new dimensions to several of the forces that influenced the design and administration of science courses in that country. The National Science Foundation Act passed by Congress in 1950 established the National Science Foundation "to promote the progress of science, to advance the national health, prosperity, and welfare, to secure the national defense; and for other purposes." (30, p. 175) For reasons that can be comprehended only by examining many deeply rooted and subtle sociological factors at work in the United States, the times seemed ripe for a federal agency to become actively involved in the construction of science courses and their administration.

Other outstanding influences on the science curriculum of secondary schools have been the launching of Sputnik in 1957, the passing of the National Defense Education Act in 1958, and the publishing of the fifty-ninth yearbook, Rethinking Science Education, by the National Society for the Study of Education in 1960. All of these influences along with a continued increase in secondary school population, an increase in the number of consolidated high schools, reports by various agencies such as the National Science Teacher's Association and the American Association for the Advancement of Science, criticisms of the existing science programs by such men as Conant and Rickover, and speeches by the President urging the schools to produce a better scientific literate citizenry have resulted in many trends in the
science curriculum of the secondary schools. Some of these trends are (1) teaching for concepts and developments of ideas, (2) movement away from verification in the laboratory towards problem-solving, (3) movement away from activities involving one class period to those involving more than one period, (4) increased emphasis on the use of laboratory as teacher demonstration, (5) increased emphasis on homogeneous grouping, (6) increased use of science clubs and science fairs—particularly specialized clubs, (7) increased emphasis on quantitative aspects of science, (8) increased use of a variety of teaching aids such as television, (9) definite emphasis on cooperative development of teaching materials by scientists, science educators and curriculum specialists, (10) increased emphasis on general education in the thirteenth and fourteenth grades and (11) increased emphasis on articulation. (9, p. 28)

B. The History of Science Education of the Republic of China

Early Days (1902-1921)

The sages in ancient China had realized that science education was the basis of all education. Education as described by the Great Learning delineated a hierarchy of education, as illustrated in the diagram on the next page.
TABLE I: THE HIERARCHY OF EDUCATION

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
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<tr>
<td>1.</td>
<td>格物 (the investigation of objects)</td>
</tr>
<tr>
<td>2.</td>
<td>致知 (to lead or bring about to understanding)</td>
</tr>
<tr>
<td>3.</td>
<td>誠意 (with sincerity)</td>
</tr>
<tr>
<td>4.</td>
<td>正心 (to regulate the heart)</td>
</tr>
<tr>
<td>5.</td>
<td>修身 (to cultivate oneself)</td>
</tr>
<tr>
<td>6.</td>
<td>齊家 (to rule the family)</td>
</tr>
<tr>
<td>7.</td>
<td>治國 (to rule a kingdom)</td>
</tr>
<tr>
<td>8.</td>
<td>平天下 (to tranquilize the empire)</td>
</tr>
</tbody>
</table>

From the hierarchy, it was clearly shown how a person could be educated, become prosperous, and the basis was: 格物 (the investigation of objectives; 格, sounds keh, means hit, or investigate; 物 sounds wu, means object), 致知 (to lead or bring about to understanding; 致 sounds chi, means lead or bring about; 知 sounds chih, means understanding). This idea is similar to Piaget's conception: to know an object is to act on it, to know is to modify, to transform the object.
(格物) and to understand the process of this transformation and as a consequence to understand the way the object is constructed (致知).
(22, pp. 176-186)

Without placing notable emphasis on the fundamental aspects of this hierarchy by Chinese descendants, the science education in China had lagged behind for thousands of years.

Under the influence of Western Culture, this hierarchy was re-examined. A combination of 格物 and 致知 is 格致学, a forerunner of physics, which was part of the curriculum of the innovated high school of 1902.

In 1912, China awoke, overthrew feudalism and established a democratic government. An innovation in education was set up, changing the private school with one teacher to the pupil high school. Physics, chemistry, and natural sciences were taught as subjects in the curriculum.

Renaissance Period (1922-1938)

During this period, the Civil War was ended and the country became unified. Scholars, who had studied in the United States, pushed the government, imitated the American educational system and began to offer six years of elementary training, three years of junior high school and three years of senior high school training.(25, p. 347)

"Outline of Science," a required course in senior high school was added to the science curriculum. The objectives and instructional methods of this course are shown in the following outline,(8, pp. 739-740)
A. Objectives

1. Emphasis is placed on scientific spirit and methods so as to straighten Chinese corrupted habits of study.
2. In order to increase the scientific knowledge, it is necessary to narrate the history of science.
3. Explain important concepts in science and stimulate the students' willingness to research.

B. Contents and methods: The teacher lectures along the prescribed headings. Each heading must be exemplified by scientific facts. Lecture-demonstration is encouraged, if necessary. After each chapter references are introduced to students for comparing and the main points of this chapter are discussed with the students. The following is a list of the prescribed headings.

1. The genesis of science
   a. curiosity
   b. practical needs
2. The evolution of knowledge: superstition—experience—correct knowledge.
5. The objectives of science: Find out the rules of phenomena, and the relationship between cause and effect.
7. A brief history of the development of science: from the superhuman strength to modern astronomy, from magic to modern physics and chemistry, from creation to modern natural evolution.

8. Outline of modern science: The relation between matter and energy, time and space.


10. The position of science in modern civilization.

Distressing and Reconstructing Period (1930-1955)

Under Japanese aggression and unrest brought about by civil war, the Chinese society became poor and backward. It was necessary to begin again when the government of the Republic of China moved to Taiwan.

Traditional subject-centered curriculum was taught in secondary school. Lecture was the main teaching activity. Students were re-doing demonstrations and cookbook exercises that served to reconfirm previously known facts. The predominant objective was college preparatory.


A. Revolution in Science Education (1955-1965)

Disciplined-centered curriculum of the United States

The most innovative and drastic changes were proposed for the science program in the period from 1955 to 1981,(5, pp. 31-34) It was during this time that the student population increased significantly in the secondary schools. The enrollments in most science courses also increased greatly, although the physical sciences were not popular at this time. It was also the period when many public critics (particularly scientists) felt that science courses in the public schools were not
doing the job of stimulating students to go into scientific vocations. The courses, they claimed, lacked rigor, were dogmatically taught, were content oriented, lacked conceptual unity, were outdated and had little bearing on what was really happening in the scientific disciplines. The functional aspects of science teaching were also attacked. Many critics believed that too much emphasis was being placed on life adjustment goals and that there was too much stress on technology. They argued that the laboratory work connected with traditional science courses consisted of exercises which developed manipulatory skills and gave students the wrong impression of the scientific enterprise. The traditional science courses were not preparing young people for understanding in either the world in which they were living or the future. Science teaching then was portrayed as dull, inadequate, and not meeting the demands of the times. The situation called for reform and change.

The real stimulus for a reform movement came from university scientists and mathematicians. These individuals claimed that the young people who entered college were very poorly prepared in science and mathematics. These scientists also felt that little was being done to encourage the talented student to go into science and mathematics fields. Since there was a shortage of scientific personnel in the United States, they decided to do something about the situation.

One of the first things which was done to initiate reform was to examine existing courses of study in science and mathematics. This examination of science textbooks of the 1950s indicated that attempts had been made to keep them up-to-date by adding bits and fragments of information to already existing content. Not only was this the case,
but traditional topics were never dropped. All in all, textbooks were a hodgepodge of information much of which was incorrect, outdated, and/or irrelevant to modern science disciplines. The reformers came to the conclusion that existing courses were not salvageable and embarked on writing new courses of study which would be in line with modern science.

According to Paul Hurd, curriculum reform in biological science had been attempted prior to 1960, but it had not been successful because of the following reasons. (15, p. 160)

1. Teachers were not aware of purposes.
2. Courses were simply a few outlined pages.
3. They failed to consider the entire learning process.
4. University did not assume the responsibility for training teachers suitable for the new programs.
5. Committees were not able to make results of their work known to large numbers.
6. Curriculum recommendations were suitable only to a small number of students.
7. None of the programs established a program of educational research needed to resolve the many problems inherent in a curriculum organization.

This was also true of the other science courses as well.

The reform movement at first had a gradual start even though the situation called for immediate change. It began with Jerrold R. Zacharias' effort to improve high school physics by developing the Physical Science Study Committee Physics Course (PSSC). When the Russians launched the first space satellite in 1957, a crash program of reform was sparked.
The public became very science conscious upon the advent of the space age. Americans were embarrassed because of the progress the Russians had made in their space program. American education was criticized from all points of view. Science and mathematics education received the most severe criticisms since these areas were directly concerned with providing scientific personnel and there was a shortage of this type of manpower.

The reform movement, which was sparked in 1957, was to produce some of the most innovative and spectacular changes in American science education ever seen in the public high schools.

The National Science Foundation and other federal agencies came into the act at this time. They were concerned about the critical shortage of scientists and mathematicians. They were also concerned with the low numbers of talented individuals who were entering scientific vocations. They attributed all of this to the deplorable state of science and mathematics teaching in the United States.

These agencies quickly discovered that science courses taught in the public high schools were staffed with unqualified teachers as well as teachers with poor and outdated science backgrounds. The National Science Foundation in particular, initiated an immediate program to improve the science and mathematics backgrounds of teachers. Colleges and universities set up institute programs sponsored by the National Science Foundation which offered courses in science and mathematics content to update teachers' science and mathematics knowledge of subject-matter.
At the same time, scientists tried to stimulate change in the science offerings in the public high schools. As a result of their efforts, a number of national curriculum groups composed primarily of scientists and mathematicians were established. Between 1957 and 1965 large amounts of funds were available from federal agencies, particularly the National Science Foundation, to bring about changes in the science and mathematics offerings in the public high schools.

The curriculum supported by federal agencies were widely adopted. The following table contains a list of the popular curricula whose adoption rate was above five percent (29).

**TABLE II: CURRICULAR SUPPORTED BY FEDERAL AGENCIES**

<table>
<thead>
<tr>
<th>Curriculum Materials</th>
<th>Percent of districts using materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-12 Science</td>
<td></td>
</tr>
<tr>
<td>1. Introductory Physical Science (IPS)</td>
<td>25</td>
</tr>
<tr>
<td>2. Biological Science: an Inquiry Into Life (BSCS yellow)</td>
<td>16</td>
</tr>
<tr>
<td>3. Biological Science: an Ecological Approach (BSCS green)</td>
<td>19</td>
</tr>
<tr>
<td>4. Chemical Education Materials study (CHEM study)</td>
<td>15</td>
</tr>
<tr>
<td>5. Probing the Natural World-Intermediate Science Curriculum Study (ISCS)</td>
<td>12</td>
</tr>
<tr>
<td>6. Project Physics Course (Harvard)</td>
<td>12</td>
</tr>
</tbody>
</table>

Table II continued overleaf...
Americanizing science education in the Republic of China and mutual-influence

As the whirlwind of revolution in science teaching whisked across the Pacific Ocean, there was an Americanization movement of science education in the Republic of China to meet the demands of the times. In 1964, PSSC, CHEMS, and BSCS were adopted as unified curriculum by the Chinese government as senior high school science courses. Being regulated by the Central Government, the reform and change were much more thorough than that of the United States.

As a result of this movement, most students in the Republic of China desired to study science and technology and then to extend their studies abroad. The proverb "come, come, come to National Taiwan University; go, go, go to the United States of America" described the situation.
Chinese students in America were excellent, they contributed their talent in developing science and technology, constructing American society, and thus strengthening cultural flow between the two countries. For example the winner of the 1976 Nobel Physics prize, finder of the J-particle, completed his secondary education in the Republic of China.

B. Innovation of Science Curriculum (1966–present)

Humanistic curriculum in the United States

The new curriculum were fairly successful in encouraging talented students to go into science and mathematics fields, and therefore provided scientific personnel for the United States. As a consequence, the advent of the Space Age was enhanced.

But the "new" curricula developed up to 1965 is now undergoing scrutiny. Many criticisms have emerged over the past decade which are forcing new directions in the teaching of science. The following are some of the important criticisms which have been made by teachers and curriculum developers and are influencing further change. (5, pp. 35–36)

1. The courses which emerged are too discipline-centered, specialized, and have a professional point of view.

2. The topics covered in these courses are similar to those covered in traditional courses of the early 1950s. In general, the topics such as human ecology, oceanography, anthropology—all important for the times and for our future—are either omitted or poorly presented.

3. The new science programs were developed independently of each other, and the topics from other sciences are used only to give
a specific topic in a course more meaning. The interrelationships of the sciences and broader meanings of science are not stressed.

4. The courses of study are too highly theory-and concept-oriented. A compromise should be sought.

5. There is a complete disregard for the relationships between science, society, technology, and the humanities.

6. The courses are considered to be too rigorous for the average student and the reading levels are too high. The courses were developed for students who normally took the traditional courses in science, but it was found that the "average" student has not been able to cope with most of these approaches.

7. Teachers find it difficult to teach these "new" courses. The courses require a special style of teaching foreign to most teachers and students. It takes several years of experience before a teacher can be effective in these approaches.

8. The courses are too long. Even though there is no stipulation which compels teachers to use the whole course of study, most teachers try to cover all of the topics. This, however, is not the fault of the curriculum but of the teacher.

9. Science in general education is not emphasized since the courses lack the humanistic, social and historical aspects so important to a liberal education. Therefore, the humanistic curriculum, and integrated science are becoming more popular.
The curriculum developed in the United States was not necessarily suitable for Chinese society, and we realize that adaptation is better than adoption. So in 1974 the Science Education Center of National Taiwan Normal University was established. It launched forth the development of Chinese science curriculum and the experiment of these curriculum.

In addition, we have paid attention to the trends in science education of the world, and have gathered more knowledge about schools, teachers, and students than ever before. We have learned some new guidelines about curriculum development. We have learned that courses of study must be developed for all types of students—the high average, the slow learner, and the disadvantaged. We have learned a great deal about the use of conceptual schemes and principles in building a curriculum. We have learned that the "discovery method" has many different meanings and that there is much to learn about concept formation. We have also realized the importance of the teacher in curriculum development and implementation. Finally, we have learned that many types of experts are need to write a course of study. Science Teachers, practicing scientists, science educators, learning psychologists should all be involved in curriculum development. The expertise of all of these individuals is needed to produce a well-balanced curriculum.
III. COMPARISON OF OBJECTIVES IN SCIENCE EDUCATION OF THE UNITED STATES AND THE REPUBLIC OF CHINA

The objectives that govern thought and action find their origin in the philosophy that men hold and in the values they hope to realize. (23, p. 6) Teaching is more than the presentation of facts. Teaching is the development of new ways of thinking—a development that reveals itself in increased skills with the problems of life, in new habit of action, in more desirable attitudes, in a benefited personality and in an improved character. A science program must be judged by its effects on individual pupils not by the number of textbook pages read or the percentage of a syllabus covered. Science can justify its place in the curriculum only when it produces important changes in young people—changes in their ways of thinking, in their habits of action, and in the values they assign to what they have and to what they do. (27, pp. 21-22)

PART I. The Development of the Objectives of Science

Teaching in the United States

To understand the present, one must know what has happened in the past. This is certainly true regarding the development of objectives for teaching science. The history of science education reveals the conditions under which science teaching objectives were formulated and the conditions under which they changed. (5, p. 27) Even the briefest survey, such as the one following, shows how the emphasis in American school science programs has shifted since 1635, and it reveals some of the pressures which have led to these alterations.
The period of the Latin Grammar school: To glorify God

The Latin grammar schools curriculum reflected the curriculum found in England around 1600. It was a classical, linguistic program and enrolled only a selected group of children. (3) The school was very authoritarian. Augustinian principles of teaching and learning were employed.

Learning cannot be promoted without discipline. The teacher has to control the child and, if necessary, has to use the cane and the strap. Thus the pupil learns to control his evil impulses and becomes conscious of the importance of obedience. (3)

Children were considered as depraved by nature. The school teacher must "whip" the children into obedience. Children had to be trained so that they would develop an attitude of obedient piety. This curriculum grew out of the idea that man's chief purpose was the glorification of God, and man had to prepare himself for the life after death. The more difficult the study, the greater value it had for discipline the child, and difficult subjects resulted in a better development of a child's mental facility. (9, p. 2)

The Period of Early Days (1750-1872): Practical and Expository

Science instruction had its real beginning in the Academy established by Benjamin Franklin in 1751. Franklin stated that the "histories of nature" should be read by all students. From such readings students learned to be better merchants, craftsmen and ministers. He assumed that a study of science would result in merchants understanding the commodities they sold, craftsmen would know how to use new materials, and ministers would be better able to understand the proofs of the
existence of God. Furthermore, ministers would be better able to present
the proofs of the existence of God more satisfactorily. Franklin felt
that science training would help man in his daily conversations with other
men. After studying science, men would become more sensitive to natural
phenomena, and many more opportunities would present themselves to afford
him additional opportunities to observe and converse with his fellow man.
Franklin's idea of science extended further than reading. He proposed
that students have actual practice in gardening and the experience of
field trips to nearby farms. The purpose of such investigations was to
observe better methods of planting and cultivation of crops. (7, pp.5-7)

Science was taught largely for information. Some of the science
textbooks were written from an inductive point of view, but science
teaching, in the early high school, was primarily by lecture and rec-
itation. The early high schools contained a limited amount of teacher
demonstration but practically no laboratory work. (9, p. 7)

The Period of College Domination (1872-1918): college preparatory

The period of college domination marked the beginning of science as
a formal discipline in the secondary schools. With this formalization,
the popularity of school science diminished. Courses were established
without regard to the students interests and need to understand their
environment.

Laboratory instruction became an important part of the science
offerings. The laboratory work was highly specialized, often dull and
stereotyped. Science was presented as a body of information in these
laboratory courses and was of little or no practical value to the
students. The main aims were to develop the ability to reason, to
observe, and to concentrate.

The various reports and syllabi beginning around 1870 caused the American high school to take on a different appearance in purpose, curriculum offerings, and psychology of teaching. Science textbooks also played a part in this change as well as being effected themselves. They were written mostly by college science teachers and often were nothing more than watered down versions of the college science course. The American high school, during the last decades of the nineteenth century, became college preparatory institutions as a result of these various influences. (7, p. 14)

Several committees—such as the Committee of Ten in 1892, the Committee of Fifteen in 1895, and the Committee of College Entrance Requirements in 1895—recommended that science be introduced into the curriculum earlier than the secondary school. This recommendation as well as other factors promoted the reorganization of the schools into 6-3-3 pattern.

The Period of Reorganization (1918-1930)

The reorganization of the schools resulted in curriculum innovations which in turn influenced the objectives of science teaching. Although the objectives of teaching science varied through the country, teachers were still primarily interested in presented scientific information. They were not particularly interested in teaching the overall principles and generalizations of science. Some teachers formulated life-centered and student-centered objectives, but these appeared to be the exception rather than the rule.
The National Education Association "Commission on the Reorganization of Secondary Education" issued a report in 1920 which recommended the reorganization of the science program in light of the seven cardinal principles of education. The cardinal principles stated by the Commission were: (5, p. 28)

1. health,
2. command of fundamental process,
3. worthy home membership,
4. vocation,
5. citizenship,
6. worthy use of leisure time, and
7. ethical character.

Attempts were made to teach general science and biology so that the seven cardinal principles could be realized. Physics and chemistry, however, continued to be college preparatory courses and were not concerned with life-centered objectives.

Although the mastery of subject matter continued to be the primary aim of science instruction in the 1920s, a great deal of work was done on the formulation of major generalizations that could be used as long-range objectives to give continuity to the science programs.

Pre-World War II and World War II (1930-1945)

Many committees published lists of objectives for teaching science during this period. The most prominent and important of these sets of statements was published in 1932 by the National Association for the Study of Education. A list of 38 generalizations that was designed to give
direction to the entire science program from grades one through twelve was proposed. One of the major strengths of this list was the balance it provided within the traditional subject matter areas and the inter-relationships it promoted among these areas. These objectives represented a broad approach to the problems involved in planning.

The use of major generalizations as objectives, especially in the form outlined in the Thirty-First Yearbook, had its limitations, because science was presented as a body of facts and students looked at science that way. The other benefits of science instruction derived from problem-solving techniques, the development of certain attitudes, and appreciations were neglected.

The Commission on Secondary School Curriculum states the following concerning the Thirty-First Yearbook of the National Society for the Study of Education. (7, p. 13)

Its greatest contribution was perhaps the plan for organizing subject-matter and learning experiences around interpretative generalizations or big-ideas which are significant for a liberal education, rather than around the laws and theories of pure science. These laws and theories are important as a means of organizing the knowledge of the scientist, whereas interpretative generalizations on the contribution of the sciences—particularly the physical sciences—have proved fruitful in the thinking of laymen for several hundred years. This proposal to employ them consciously in a program of education represents a significant step forward.

The Commission on Secondary School Curriculum published Science in General Education in 1938, which stressed the need to correlate science with the problems of living and indicated the desirability of selecting content that was useful to boys and girls. This committee advocated the teaching of science around four basic aspects of living: (1) personal living, (2) immediate personal-social relationships, (3) social-
civic relationships, and (4) economic relationships. (7, p. 27) This report further gives a guide to suggest how teachers can use the report to facilitate teaching for the basic aspects of living. This report is significant because it introduces a new philosophy of science instruction. Burnett states that "one of its chief contributions lay in its analysis of the use of reflective thinking in the solution of problems." (3, p. 81)

Post World War II (1945-1955)

Science teaching placed notable emphasis on the functional aspects of science. Many organizations such as the National Association of Secondary School Principals, National Education Association, and the American Association of School Administrators published statements of objectives for the teaching of science in the secondary schools. The most important statement concerning science instruction was that of the National Society for the Study of Education as presented in its Forty-Sixth Yearbook, Part I. The development of objectives in science education between 1932 and 1945 was summarized. During this period science instruction followed the trends of objectives in general education. Less emphasis was placed on the memorization of information and more emphasis on teaching boys and girls the functional aspects of science. The understanding of scientific principles and developing problem solving abilities were stressed to a greater degree than in the past. However, teaching scientific information was still considered to be the most important aim of science teaching. After World War II, teachers stressed such objectives as developing scientific concepts, principles, skills, and attitudes. Skill in problem solving became a primary aim. An infallible scientific method that could be used as a pattern to gather information was deemed
The laboratory took on a new importance as the primary place where this method was used. Skills in gathering and testing data, in identifying and solving problems, and in examining the validity of conclusions were strongly encouraged as the aims of science education. Nevertheless, the older, well-established aim of teaching scientific information was not abandoned as being unworthy. Instead, the relative values of the objectives were reassessed as the newer goals were added.

The National Society for the Study of Education published the following categories of objectives in 1947 which reflect this type of teaching:

(27, pp. 23-24)

1. functional information of facts,
2. functional concepts,
3. functional understanding of principles,
4. instrumental skills,
5. problem solving skills,
6. attitudes,
7. appreciations, and
8. interests.

The objectives in the Forty-Sixth Yearbook are stated in such broad terms that their implications to science teaching may not be immediately obvious. The professional literature of the late 1940s cites many attempts to break down these broad objectives into useable form. Curriculum groups spent a considerable amount of time on this aspect of planning. Only when a variety of experiences are incorporated into the science curriculum can students begin to advance toward the attainment of these broad objectives, measuring goals of such scope is difficult if not impossible.
Revolution in Science Teaching (1955-1965)

Course content improvement studies

In 1957, the Russians launched the first space satellite, threatened the safety of the United States and Americans were embarrassed because of the lack of progress in American programs. A reform movement was sparked to produce some of the most innovative and spectacular changes in American science education.

Many new approaches were produced by national curriculum groups until 1965. All of these approaches attempted to lead students through a series of experiences which encouraged the creative process and to bring them to a point where they conceptualized the scientific knowledge they obtained. Students were thought to end up with an understanding and appreciation of the true nature of science: That is, the structure of science and the strategies of science. In these courses students spent a great deal of time in the laboratory performing experiments which were truly investigations. Students were not re-doing demonstrations and cookbook exercises that serve only to reconfirm previously known facts. Students were involved with the anticipation of things learned and to be learned. Not only were students directly involved with "discovery" but they also learned about the limitations of science and the scientific enterprise. In short, the objective of science education is scientific literacy, to train technical specialists, and to provide scientific personnel for the United States.

Humanistic Science Curriculum (1966-1980)

The National Science Teachers Association Committee on Curriculum Studies K-12, in a position statement on School Science Education for
the 1970s, states the following:

The major goal of science education is to develop scientifically literate and personally concerned individuals with a high competence for rational thought and action. This choice of goals is based on the belief that achieving scientific literacy involves the development of attitudes, process skills, and concepts necessary to meet the more general goals of all education.

Some of the general goals of science education listed by the committee (19) include the following:

1. learning how to learn, how to attack new problems, how to acquire new knowledge,
2. using rational processes,
3. building competence in basic skills,
4. developing intellectual skills and vocational competence,
5. exploring values in new experiences,
6. understanding concepts and generalizations, and
7. learning to live harmoniously within the biosphere.

The Committee emphasizes the importance of developing scientifically literate citizens having the "necessary intellectual resources, values, attitudes, and inquiry skills to promote the development of man as a rational human." The scientifically literate person according to the committee is one who: (19)

1. uses science concepts, process skills, and values in making everyday decisions as he interacts with other people and with his environment,
2. understands that the generation of scientific knowledge depends upon the inquiry process and upon conceptual theories,
3. distinguishes between scientific evidence and personal opinion,
4. identifies the relationship between facts and theory,
5. recognizes the limitations as well as the usefulness of science and technology in advancing human welfare,
6. understands the interrelationship between science technology and other facets of society including social and economic development,
7. recognizes the human origin of science and understands that scientific knowledge is tentative, subject to change as evidence accumulates,
8. has sufficient knowledge and experience so that he can appreciate the scientific work being carried out by others,
9. has a richer and more exciting view of the world as a result of his science education,
10. has adopted values similar to those that underlie science so that he can use and enjoy science for its intellectual stimulation, its elegance of explanation and its excitement of inquiry, and
11. continues to inquire and increase his scientific knowledge throughout his life.

In addition to the characteristics identified above, Dr. Thomas P. Evans considers the scientifically literate person as (a) possesses objectivity, (b) has faith in and values logical reasoning, (c) rejects myths and superstitions, (d) accepts conclusions when supported by data, (e) is critical and skeptical, (f) displays the habit of weighing evidence, and (g) uses the methods of science to solve problems when the methods are appropriate. (10)
One of the main purposes of American education is to provide the experiences through which young people can acquire the knowledge, skills, attitudes, and values that lead to patterns of behavior beneficial to the democratic society in which we live. "Scientific literacy" is obviously part of the general pattern.

PART II. Objectives of the 1980s and beyond: Some perspective cultivate the student's ability to make the best decision and control his own fate. (28, p. 2)

The objectives of science education of the secondary schools in the Republic of China are: To continue the science education in the primary schools and to develop scientifically literate citizens with a high competence for rational thought and action so as to strengthen the scientific and technological foundation in the Republic of China. The following must be done by students in order to reach these objectives:

1. to know that the essence of science is the combination of facts, concepts and processes,
2. to know the objectives of studying science is to understand the natural environments and to improve human lives,
3. to be perspicacious to scientific concept, practice scientific methods, and cultivate scientific attitudes so as to apply to daily life and to give continuity to further study, and
4. to develop the researching interest, creating power, and independent judging spirit so as to reach the purpose of science education for all people.
Comparison of objectives

The revolution of science teaching in the United States in 1960s has promoted the advent of the Space Age. But the courses of study are too highly theory-and concept-oriented. The courses are considered to be too rigorous for the average student. Science in general education is not emphasized since the courses lack the humanistic, social, and historical aspects so important to a liberal education. There is a complete disregard for the relationships between science, social science, and the humanities. The results of this kind of discipline-centered science education are, the depression of moral concept, the excessive waste of natural resources, and the dropping out from science classes and society in general by large numbers of students.

The authorities of the Republic of China are deeply aware of these consequences. The objectives of science education for the Republic of China in the near future follows: (4, p. 5)

a. on the humanistic ground, to promote the valuation of mankind, solidify the dignity of personality, and increase the happiness of life,

b. to push the movement of science for all people so that the masses can think scientifically, behave scientifically, and enjoy the use of materials scientifically, and

c. emphasize the science education of scientific concept, scientific process, and scientific attitude, so as to mold the adolescent to become a scientifically literate citizen.
IV. OVERVIEW OF INSTRUCTIONAL METHODS AND PROCEDURES IN SCIENCE TEACHING OF THE UNITED STATES AND THE REPUBLIC OF CHINA

PART I. The Need for Various Instructional Methods

Many methods and procedures are available to science teachers. They have at their disposal many ways of teaching students. The reasons that support the use of various methods are the following: (23, pp. 68-69)

1. Some objectives are better served by one procedure than by another. For example, in a class that is trying to learn certain facts and principles concerning fertilizers and plant growth, the project approach may be effective, whereas in another class concerned with the functioning of the cyclotron and syncrotron, a discussion which utilizes various audiovisual materials may be advisable.

2. The use of several avenues gives multiple opportunities to learn. Some students learn effectively through one avenue; others through another. Through a variety of opportunities, the individual needs of students can be more nearly set.

3. The nature of the content may determine the method that can be used. To develop an understanding of the processes involved in the coking of coal and the nature of the products, a field trip may be essential while teaching oxidation-reduction may involve a thermal reaction for which a demonstration can serve more effectively.
4. There is merit in variety just to avoid monotony. Students appreciate the teacher's efforts to make their work more interesting and more effective. Different methods of teaching may be considered separately for sake of clarity. In actual teaching the methods employed should flow rather easily from one to another, creating desirable and essential conditions for student learning and growth. In the choice of teaching method, it is well to bear in mind that a class period is not necessarily limited to the use of one method; within a given time several methods may actually be employed.

The various methods infrequently used are: laboratory work, demonstration, project work, discussion, directed study, lecture, text-recitation, committee work, field trip, reports, evaluation, using audiovisual materials, programmed instruction, environmental studies, lecture-demonstration discussion, team-teaching, individualized and self-paced instruction, etc.

PART II. Overview of Methods of Science Teaching in the United States and the Republic of China


It is almost certain that the course will be centered on the textbook. The class will be assigned reading material from a chapter, in slow sections. This material may be read aloud in class. The teacher may then either lecture to the class or he may lead a discussion with the class. Questions at the end of each chapter are assigned and later discussed. This is a typical daily presentation.

Junior high science, in particular general science, is characterized by the lecture-demonstration method, the text-recitation
method, class discussion, and supervised study. A laboratory period is seldom involved in the program for at least two reasons: First, many studies in the 1930s demonstrated that achievement in the sciences is not related to the inclusion of the laboratory as a method. Similar studies showed that the lecture-demonstration method of presentation was superior for developing immediate retention of factual information. Students in high school science did as well on achievement tests when the laboratory was not a part of the instructional program. Science teachers apparently read the research and acted upon it; the laboratory in general science was abandoned before it was adopted generally by the public schools. Second, more practical considerations were also causal in the choice of method. Junior high schools were and are overcrowded; hence, the mere size of the class makes the inclusion of laboratory work impossible. Moreover, school systems have seldom budgeted funds to equip general science classrooms for individual or for small-group experiments.

Fowler's descriptions about the science education in the United States were just like those in the Republic of China in the 1970s. The greatest barriers that prevented progress of science education in the Republic of China were that classes were and are over-crowded and the competition for entrance examination is very keen. There are about fifty students in a class. Such large numbers makes the individualized instruction, class discussion, and small-group experiment hard to carry out. So the lecture and lecture-demonstrations are popular for science education. Students lay stress on text-memorization. Teachers guide students on how to pass the examination. The true meaning of science education, teaching students the processes of creating scientific knowledge by experiments, is put aside. The situation needs to be changed and reformed to meet the demands of the times.

In order to improve the methods of science teaching in the Republic of China and strengthen the cultural interflow between Sino-American, a workshop on physics and chemistry teaching was held on March, 1980 in Taiwan, and the author was a member of this workshop. An appendix
about the workshop is attached to the thesis.

Comparison of theory of learning

Experiments are commonly regarded as the heart of science education. But today students should not be re-doing demonstrations and cookbook exercises that serve only to reconfirm previously known facts. Instead they should spend a great deal of time in the laboratory performing experiments which are truly investigations. Psychologists have provided various theories of learning regarding such investigations.

Robert M. Gagne, Jerome S. Bruner, and David P. Ausubel are three well known psychologists whose theories have been adopted by science educators. These three psychologists have provided science teachers and professional science educators with different, general positions regarding the learning and teaching processes. From these positions comes most of the psychological controversy surrounding the teaching and learning of science.

According to Shulman; (24) Gagne, Bruner, and Ausubel present two fundamental positions regarding the objectives of education. On one hand, Gagne and Bruner maintain that the objective of education is to produce individuals who are competent in the processes of attaining knowledge. Examples of these processes are inferring, predicting, controlling variables, and hypothesizing. Ausubel, on the other hand, argues that the emphasis in education should not be on the processes of learning but instead on the products of learning (facts, concepts, principles, conceptual schemes, etc.).

With respect to the means of reaching these objectives, Shulman sees the three psychologists aligning themselves with two fundamental positions.
The dimension along which the disagreement lies is the amount of guidance given to the learners. This time Ausubel and Gagne are allies, both of them believing that learning should be maximally guided so the learner's task is primarily that of receiving what is to be learned (receptive learning). Bruner alone stresses a more free, unguided approach to learning in which the learner's task is that of discovery (discovery learning).

The Science Education Center of National Taiwan Normal University has developed an integrated curriculum for junior high school. It integrates physics and chemistry. This will be a unified curriculum for all junior high schools in the Republic of China.

The major objective of these courses is to cultivate individuals who are competent in the knowledge-gathering process and subject matter products. This is based on the belief that achieving scientific literacy involves the development of attitudes, process skills, and concepts necessary to meet the more general goal of all education. The process of reaching the objective is guided discovery with emphasis upon individualized instruction.

Bruner said: "Any subject can be taught effectively in some intellectually honest form to any child at any stage of development." (2) The results of this concept may have resulted in many young talented students becoming outstanding scientists, but it also has caused many average students to flunk their science courses. Being aware of this demerit, the new curriculum of the Republic of China pays attention to the science education of all people, so emphasizes the individualized instruction.

The following table will clarify these positions:
TABLE III: COMPARISON OF THEORY OF LEARNING

<table>
<thead>
<tr>
<th>The Objectives of Education</th>
<th>The Instructional Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ausubel</td>
<td>Reception (maximally guided—meaningful verbal learning)</td>
</tr>
<tr>
<td>Bruner</td>
<td>Independent Discovery</td>
</tr>
<tr>
<td>Gagne</td>
<td>Reception (maximally guided)</td>
</tr>
<tr>
<td>The Republic of China</td>
<td>Guided discovery with emphasis upon individualized instruction</td>
</tr>
</tbody>
</table>

Comparison of the current situations (June 1981)

Table IV shows a comparison between the current situations in science education in the United States and the Republic of China.

TABLE IV. COMPARISON OF THE CURRENT SITUATIONS ABOUT THE SCIENCE EDUCATION IN THE UNITED STATES AND THE REPUBLIC OF CHINA

<table>
<thead>
<tr>
<th>Country</th>
<th>United States</th>
<th>Republic of China</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research about the fundamentals of science education (14, p.77)</td>
<td>Yes, e.g.: &quot;Research on Cognitive Process and the structure of knowledge in Science and Mathematics&quot; was supported by NSF.</td>
<td>Is lacking in the research about this area,</td>
</tr>
</tbody>
</table>

Table IV continued overleaf...
<table>
<thead>
<tr>
<th>Country</th>
<th>United States</th>
<th>Republic of China</th>
</tr>
</thead>
<tbody>
<tr>
<td>Law provided for the development of science education.</td>
<td>In 1958 Congress passed the National Defense Education Act.</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-service teacher education.</td>
<td>Convenient</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instructional materials</td>
<td>Diversified</td>
<td>Unified</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social resources</td>
<td>Science education was supported by various kinds of social resource.</td>
<td>Few</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compulsory education</td>
<td>Twelve years</td>
<td>Nine years</td>
</tr>
<tr>
<td>Special science-classroom</td>
<td>Is popular, it is a combination of instrument store-room, laboratory, reference room, and classroom.</td>
<td>Few</td>
</tr>
<tr>
<td>Contents of science education</td>
<td>Scientific science education</td>
<td>Literary science education</td>
</tr>
<tr>
<td>Competition in entrance examinations</td>
<td>Easy</td>
<td>Keen</td>
</tr>
</tbody>
</table>

Table IV continued overleaf..
### Table IV continued

<table>
<thead>
<tr>
<th>Item</th>
<th>United States</th>
<th>Republic of China</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher strikes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Individualized instruction</td>
<td>Became popular</td>
<td>Under experiment</td>
</tr>
<tr>
<td>Rate of student's absence</td>
<td>Approach 10% daily in large cities.</td>
<td>Less</td>
</tr>
</tbody>
</table>

#### V. SUMMARY AND CONCLUSIONS

**Summary**

The report has sought to compare science education in the secondary school of the United States with that of the Republic of China.

The United States has a widely extended territory, abundant natural resources, democratic system, and scarce population density. This open society enables the theoretical advancement and development of science education. The supreme objectives for developing science education seem to be to conquer nature and the universe, and to assume the scientific leadership in the world.

On the contrary, the Republic of China now possesses several islands, with limited natural resource, denser population density and under the threat of Communist aggression. The objectives of developing science
education is for survival, national security, and to promote the society to a prosperous status.

The ancestors of the United States, struggling with their environments after they colonized America, made a splendid effort in developing science education.

There was no science education in ancient China, but Chinese sages had realized that science education (格物，致知) was the basis of all education. Nevertheless, life in ancient Chinese society was self-content, and it was too expensive to develop science education. As a consequence, the developing of science education was ignored.

According to J. Bronowshki's Science and Human Values, independence and originality, dissent and freedom, and tolerance: such are the first needs of science. (1, p. 62) But the East has the habit of mystic submission to truth, and the way of looking for truth is to find concepts which are beyond challenge, because they are held by faith or by authority or the conviction that they are self-evident. (1, p. 45) Tolerance alone is not enough: This is why the bland, kindly civilizations of the East, where to contradict is a personal affront, developed no strong science. (1, p. 63) Inheriting from the background of this historic culture, today the Republic of China has the willingness to pay special efforts to develop science education. In 1964 the Republic of China adopted Physical Science Study Committee Physics Course, Chemical Education Materials Study, Biological Sciences Curriculum Study as her instructional materials for science education in senior high schools, and later, starting in 1976, using Intermediate Science Curriculum Study as references to develop Chinese physics and chemistry
textbook materials of the junior high schools, and continued to update the level of science education in that country.

The history of the science education of the American secondary schools is traced from the first school established in 1635 to the present. A summary of the science curriculum in the secondary schools might be classified in the following general periods. This classification is not in terms of science offerings but in terms of the outcomes hoped for science teaching. (9, p. 29)

1635-1617 The Latin grammar school: no science
1750-1871 The academy and public high school: actual and expository
1872-1918 Standardization of the curriculum: college preparatory
1918-1956 The period of reorganization: evolution from college preparatory towards functional
1956-1970 Revolution in science education: functional and college preparatory--tendency towards college preparatory
1970-present Humanistic curriculum: to develop scientifically literate citizens.

Conclusions

Science can be a path to the greatest fulfillment and self-actualization for an individual. (21) Education is a proposed procedure to develop the ability of an individual. Therefore, science education is a proposed procedure that helps an individual to go through the path of the greatest fulfillment and self-actualization.

Taipei and Washington D.C., are located on opposite sides of the globe, but the people on either side have shared the same lofty idea of
freedom, pursuit of happiness and self-actualization for an individual; so both people lay stress on developing science education.

The development of science education in the United States has her peculiar activities and vital forces that attracts the Republic of China to imitate her achievements. On the other hand, the Republic of China, with her profound historical culture and deep comprehension about the evolution of science education in the United States, has oriented her own direction of developing science education. But both peoples hope that the satisfaction and pleasure of life that could come with the creative, imaginative use of the power of the mind for the scientific investigation which with concerted effort could result in the peoples of the earth enjoying peace together. (26)
BIBLIOGRAPHY


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APPENDIX

The Address to Sino-American Workshops on
Physics and Chemistry Teaching
GREETINGS

Friends! Friends is a special term which in the English language brings with it many positive feelings based on shared experiences which may have been pleasant but possibly trying. It is a privilege for me to use "Friends" in addressing you, arising from my first perceptions of
Chinese culture as a boy of 12 eating "100 year old eggs" in the home of a Chinese scientist, to this visit which is my fourth since 1976. I bring personal greetings from the wintry state of Wisconsin to each of you. I offer our deepest appreciation to the many who through their contributions of time and financial support have made this seminar possible, in particular, the executives of National Taiwan Normal University, Taiwan Provincial College of Education, Kaohsiung Teachers' College, with the sponsorship of the Ministry of Education, National Science Council, Taiwan Provincial Government, Taipei Municipal Government, and Kaohsiung Municipal Government.

CONTEXT

Just as this seminar was not conceived in a vacuum but rather originated in a context, that of the many discussions held with administrators and faculty both here and in Wisconsin, so, science and the study of science is properly considered in the context of the society in which it is studied.

PRIMARY SCHOOL ART

On the morning of April 1, 1978, I had the opportunity to visit here in Taipei, along with my wife and 70 students of our University of River Falls Concert Choir, the outstanding school Dwen Hwa. Each of us was impressed with the positive attitude and buoyancy of the students but particularly with the quality of the teaching and the learning. In talking with the teachers, it was interesting to note their evaluation of the childrens' art work, having identified it as that of primary
children. We, from Wisconsin, identified it first of all, not as simply children's art but as oriental children's art. The distinction was obvious when pointed out, but not immediately perceived by those in the culture.

ASTRONOMY CRAB NEBULA

Similar events can take place in science in spite of a concerted and determined effort to be completely objective and analytical. It is very interesting to note that on July 4, 1054 A.D., a light appeared which was so bright that it could be seen in the sky even with the brightness of the day at noon. How do we know of this? We know this now for several reasons, not because of the recording of the event in what is now Europe, for this was the period of the Dark Ages and the interests were not in that of observing such events. We know because of the carefully recorded observations of the Chinese astronomers at that time. For years contemporary astronomers have searched for evidence that someone in another part of the world had witnessed the supernova which we now call the Crab Nebula. The point I would make is that though the event was there to see and record by many in the society of that time, the proper context for supporting or having the observation made and recorded existed uniquely in only several locations. Several, because just a few years ago a team of NASA (National Aeronautics and Space Administration) and university astronomers together with United States park rangers identified ancient Native American or Indian rock carvings and paintings at widely separated sites in the Southwest portion of the United States detailing this event. One of them in the Village
of the great Kivas near Zuni, New Mexico.

I believe this is an indication of the sophistication of the Chinese society of that time. It is also an indication to us that the society in which we live shapes our view, understanding, and perception of that which goes on around us in life.

CRISIS

I am told that your Chinese symbol for crisis is that obtained by the juxtaposition of two other symbols, one for danger and the other for opportunity. The science and society enjoy a similar juxtaposition today as they have in the past. For example, the development of the knowledge for the use of nuclear energy resulted in the use of the atomic bomb on Hiroshima and Nagasaki on August 3 and 6, 1945. But this knowledge has also provided for many lifesaving and life-extending activities, including the use of radioactive tracers in humans and the use of cobalt 60 in the treatment of cancer. A danger, and opportunity, and a crisis.

THE MIND, THE BRAIN, THE GREAT FRONTIER

To identify, to analyze, and to solve the great problems that people face in this universe will require the use of one of the most powerful forces on earth—that of the mind, the brain. This mass, averaging 1.36 Kg is regarded by those who have studied it as being one of the most powerful forces on earth, yet surprisingly, it lacks the ability to fully understand itself. The ability to deal selectively with the 100 million messages each second that comes to it is impressive by itself. The memory site storage capability equivalency of 10 billion
pages of the type in the Encyclopedia Britanica is mind boggling. The discoveries of recent years underscore, as mentioned earlier, the dependency or strong affect that environment can have on understanding and research.

Acupuncture, used in the society here for over 2,000 years, has been used for medical anesthesia during surgery in the last decades. Endorphins, discovered in the brain in 1975, have been measured in the body apparently directly resultant from the use of acupuncture.

Diagrams and study of the ear have long been a part of the Chinese tradition used to determine the condition, and medical history of a person. Recent clinical investigations have shown direct electrical signals on the surface of the ear related to the part of the body as had been diagrammed by Chinese for centuries.

Each of these illustrations had been foreign and even suspect by American clinicians until recent years. But now, the bridge between the cultures, and between the practice and the ability to explain the practice has proven beneficial to each of the cultures and to the advance of science.

WEALTH AND LOGS

Service to society is to me one of the very important concepts and foundations for life. A very touching and poignant story was graphically illustrated for me two years ago here in this country in March. As we approached a hotel several hours drive from Taipei, I noted a particularly striking sculpture of an ox straining to pull a load of logs. The strength of the sculpture so impressed me that I pointed it out to
(and discussed it with) a number of our university students. It was later that a fuller meaning and appreciation was developed when a dear Chinese friend explained that the pronunciation for log and wealth in Chinese is very close and if not carefully done perhaps indistinguishable. When the sculpture was first set in place by the hotel, the ox was pulling the load of logs towards the hotel. When this was observed by the owner of the hotel, an immediate change was made, that of having the ox pull the load of logs (wealth) away from the hotel in order that it would properly symbolize the sharing of the wealth with society rather than the accumulation of it for an individual.

The incentive to learn, investigate, and produce needs to be there. However, it is as important as in the case of the load of logs, to be moved to share the riches of life through the investigation of science with our society.

**RICE, SNOW, CAMELS, HUNGER**

Our environment, the context of our lives, and our language both mold and reflect our lives, the items we value, and priorities. In Norway there are some 15 expressions which may be used to describe the character of snow, in Arab countries there are 20 some words which can be used to describe diseases of camels, in Oriental languages there are dozens of terms used to describe types of rice and preparations, in many developing countries there are more than 20 terms used to describe the various stages of hunger from the first pangs to the final throes of starvation.
CONCLUSION

Our closing wish would be that each language on earth might have dozens of terms to fully describe the satisfaction and pleasure of life that could come with the creative, imaginative use of the power of the mind for the scientific investigation which with concerted effort could result in the peoples of the earth enjoying peace together.